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THE GRASSES OF IOWA

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THE GRASSES OF IOWA

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THE law creating the Iowa Geological Survey provides for the publication of Bulletins on subjects of economic interest relating to the Natural History of the State. It is with sincere pleasure that the Survey now presents to the people of Iowa, Bulletin Number 1. This volume treats of the Grasses of Iowa, a subject of p imary importance to the rapidly developing agricultural interests of the state. The preparation of the volume involved an immense amount of careful and conscientious work, but it was all done as a labor of love on the part of the authors. The work is submitted in the confident belief that it will be of the highest value to the great industry that so conspicuously transcends all other industries in our magnificent state.

SAMUEL CALVIN,
State Geologist.

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GRASSES OF IOWA.

PART I.

INTRODUCTION.

No apology is needed for a work describing the grasses of Iowa. The importance of Iowa as an agricultural state depends largely on the value of products derived from members of the grass family, such as corn, oats, blue grass, wheat, etc. Iowa's wealth depends largely on the produce derived from the grasses and cereals.

The work on grasses may be divided into two parts: First, economic considerations on cereals and grasses, especially with reference to general structure, the seed and its germination and vitality, the cereal production of the state as compared with other parts of the world, climatology of some of our most important cereals, grasses in medicines, pastures and meadows of Iowa, their chemical composition, the fungus diseases of our cereals and grasses, and means of prevention. It is only in a few instances that we are provided with precise knowledge of the changes that occur in grasses during their development. This is an important subject and can only be solved through a series of continued investigations.

So far as possible the grasses have all been figured. One-third have been drawn expressly for this work by Miss Charlotte M. King. Some have been photographed by Dr. S. W. Beyer. F. D. Coburn and Mr. Charles N. Page also supplied a few cuts, and we are especially indebted to the United States Department of Agriculture. The descriptive part is supplied mostly by F. Lamson-Scribner. He has also kindly examined all the grasses in the collection and those of the State University of Iowa. The economic, ecological notes and accounts of diseases, as well as the original chemical matter, should be attributed to the senior authors. Thanks are due to the following persons who have contributed specimens: Mr. E. W. D. Holway, Decorah, Iowa; Prof. P. H. Rolfs, Clemson College, S. C.; Prof. H. W. Norris, Grinnell, Iowa; Prof. B. Fink, Fayette; Prof. A. S. Hitchcock, Manhattan, Kan.; Dr. M. Reynolds, Minneapolis, Minn.; F. C. Stewart, Geneva, N. Y.; F.

A. Sirrine, Jamaica, N. Y.; Prof. E. E. Kaufman, Fargo, N. D.; Prof. G. W. Carver, Tuskeegee, Ala.; F. Reppert, Muscatine; Prof. C. E. Bessey, Lincoln, Neb.; Bandusia Wakefield, Sioux City; A. A. Miller, Davenport; W. D. Barnes, Blue Grass; C. A. Wilson, J. I. Schulte, C. R. Ball, W. E. Gossard, C. O. Pool, W. Newell, Charles Le Buhn, A. F. Sample, J. H. Rolfs, Emma Sirrine, C. B. Weaver, B. H. Hibbard, H. C. Taylor, A. P. Whitmore, W. H. Warden, C. E. Eckles, Miss A. Estella Paddock, H. H. Hume, C. A. Battles, H. A. Crawford, W. D. Fitzwater, H. O. Sampson, Geo. F. Sokol, E. R. Hodson, L. R. Walker and other students of the Agricultural College.

Specimens sent from F. Reppert of Muscatine, W. D. Barnes of Blue Grass, A. A. Miller of Davenport, J. H. Mills of Mount Pleasant, R. I. Cratty of Armstrong, and B. Fink of Fayette, are especially worthy of mention. Several local species are found in the vicinity of Muscatine and Davenport which do not occur elsewhere in the state. We wish also to express our special thanks to Prof. T. H. Macbride and B. Shimek of the State University of Iowa. The latter has not only favored us with specimens, but has gone through the entire collection of the State University and listed such as were determined by Professor Lamson-Scribner. We wish also to express thanks for uniform courtesy shown us by the Division of Agrostology of the United States Department of Agriculture. We are also indebted to Dr. William Trelease of the Missouri Botanical Garden for the use of books, to Dr. Robinson of Gray Herbarium of Harvard University for having kindly looked up the specimens referred to in Gray's Manual, sixth edition; to Dr. Harshberger of the University of Pennsylvania for the specimens of *Zea canina* and its hybrids with *Euchlaena;* Prof. G. W. Carver for help on fungus diseases of grasses, and Dr. H. Foster Bain and Dr. Calvin, who encouraged the work in every way. We wish also to express our thanks to the agricultural press of this state, which has kindly assisted us in every way possible in making a complete collection of our grasses. Special mention should be made of the volunteer observers of the Iowa State Weather Service, who have in every way assisted us. Their notes and specimens have been of much value to us. Special thanks are also due to Miss Emma Sirrine, Dr. H. Foster Bain, Dr. S. Calvin; to C. R. Ball, and R. Combs, who assisted in preparing the bibliography; to Dr. S. W. Beyer, who made most of the photographs; C. B. Weaver and several students,

vho made some of the drawings representing anatomy of eaves, and Miss Charlotte M. King, for faithful drawings. 'hanks are due also to Mrs. M. S. Schoonover, Miss Nellie 'ewman and Miss Loughran for clerical help.

The names of collectors and of localities will be found in ieir appropriate connection. We trust that this volume, a preninary one of the botanical series, will meet with the approval of botanists as well as the people of the state.

The chemical analyses of the grasses, presented in this work, were made by the chemical section of the Experiment Station, and the faithful service of Messrs. Mead and Grettenurg have added largely to the completeness of the work.

L. H. PAMMEL,
J. B. WEEMS.

Ames, Iowa, November 1, 1899.

GRASSES—GRAMINEÆ.

General Description.

Characters of the Order.—Fibrous-rooted, annual or perennial, herbaceous plants (among our species Arundinaria alone is woody), with usually hollow, cylindrical (rarely flattened) and jointed stems (culms) whose internodes for more or less of their length are completely enveloped by the sheath-like basal portion of the two-ranked and usually linear, parallel-veined leaves.

Flowers without any distinct perianth, hermaphrodite or rarely unisexual, solitary or several together, in spikelets, these disposed in panicles, racemes or spikes, and consisting of a shortened axis (the rachilla) and two or more chaff-like, distichous bracts (glumes), of which the first two, rarely one or none or more than two, are empty (empty glumes); in the axil of each of the succeeding bracts (except sometimes the uppermost) is borne a flower (hence these are named flowering glumes). Opposed to each flowering glume, with its back turned toward the rachilla, is (usually) a two-nerved, two-keeled bract or prophyllum (the palea), which frequently envelops the flower by its enfolded edges. This bract is the prophyllum of the extremely short axis or branch which supports the flower; its absence indicates that the flower is strictly sessile or inserted directly on the rachilla; the rachilla or axis of the spikelet may or may not be produced beyond the palea. At the base of the flower, between it and its glume, are usually two very small hyaline scales (lodicules); rarely there is a third lodicule between the flower and the palea. Stamens, usually three (rarely two or one, or more than three), with very slender filaments and two-celled, usually versatile anthers. Pistil with a one-celled, one-ovuled ovary, and one to three, usually two, styles, with variously-branched, most frequently plumose, stigmas. Fruit, a true caryopsis, rich in albumen. (In Sporobolus and Eleusine the fruit is a utricle, the seed being loose within the thin pericarp.) Embryo small, lying at the front and base of the seed, covered only by the thin pericarp.

The organs or parts of grasses, as in other plants, are those of vegetation and those of reproduction; to the first belong the root, stem or culm, and leaves; to the second the stamens and pistils.

Roots.

Gross characters.—Grass roots are always fibrous. The more or less strong underground rhizomes are often called roots; they are not true roots, but are specially modified stems.

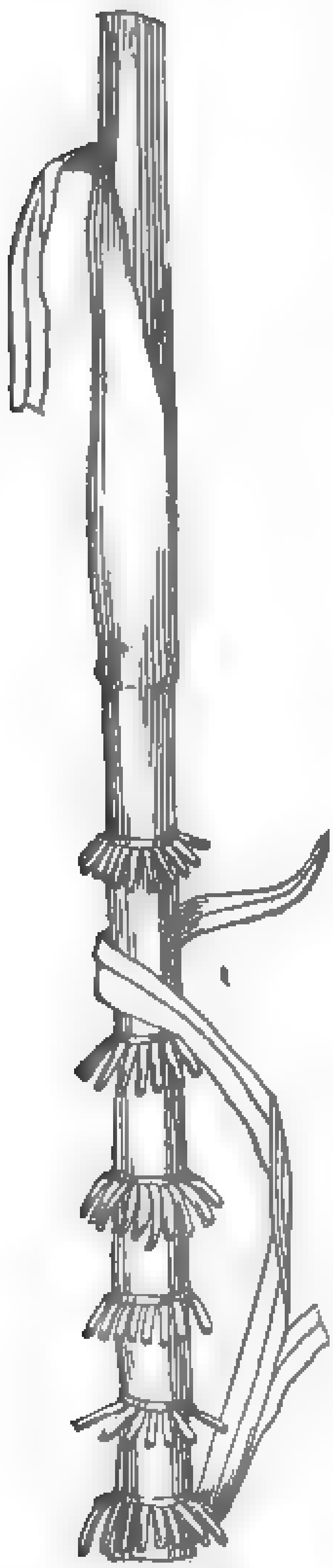


Fig. 1. Brace roots of Mexican corn grown on college farm. (King.)

Minute anatomy.—The purpose or function of the roots is to obtain nutrient material from the soil and conduct these matters through certain channels. It is important, therefore, to consider the structure of the roots from an anatomical standpoint. One

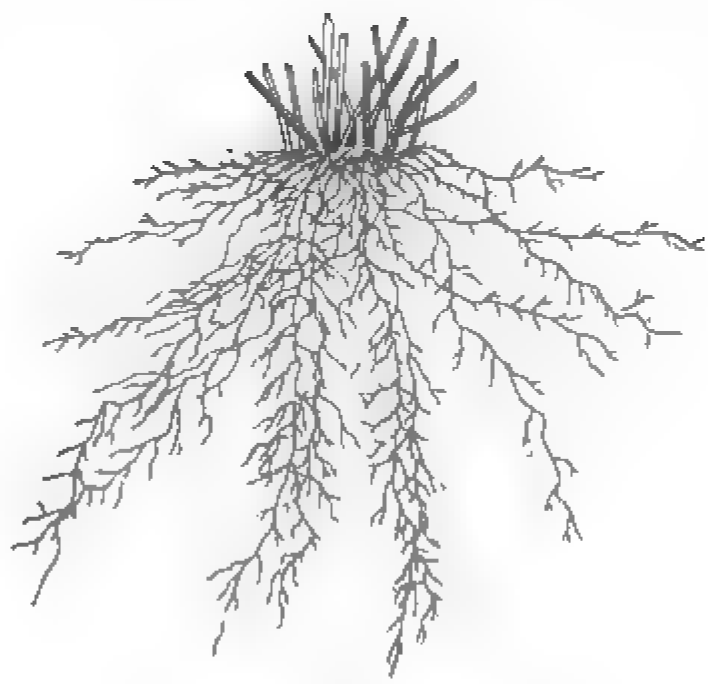


Fig. 2. Blue grass and its system of roots. (King.)

illustration will serve to show the structure, and for that purpose the corn plant may be taken as a type.*

The first root is early formed by the plant; it exists in the seed. When appropriate material, moisture, warmth and oxygen is

*For literature see: J. W. Harshberger. Maize; A Botanical and Economic Study. Contr. Bot. Lab. Uni. Penn. 1: 75-202. 1893. Strasburger, Noll, Schenck and Schimper Lehrbuch der Botanik 658, 1894. J. Sach's Lecture on the Physiology of Plants; English translation by H. Marshall Ward. A Text-book of Botany. 858: 461 f. G. Haberlandt. Physiologische Pflanzenanatomie. 560: 235 *f*. De Bary, Comparative Anatomy of the Vegetative Organs of the Phanerogams and Ferns; English translation by F. O. Bower and D. H. Scott. 650: 241 *f*.

furnished to the seed the root pushes through the covering of the seed and enters the soil. At this early stage it is easy to make out a conical tip known as the root-cap. This consists of loosely arranged parenchyma cells. These cells are not alike, but differ in size and shape. It is easy to observe that the cells at a point back of the tip converge; they are destined for a different purpose from the cells above and below. This point is known as the growing point or punctum vegetationis. All other cells are derived from the growing point. Below, the cells of the root-cap are formed. These are continually being removed as the roots push through the soil. The root-cap is purely protective in its function. In the center occurs what is known as the central cylinder (plerome). On either side occurs the cortex (periblem). The outer layer is the epidermis (dermatogen). These cell walls are more or less mucilaginous. All of these young cells contain an abundance of protoplasm and a distinct nucleus. At a little distance back of the tip, the epidermal cells form root hairs. These are at first straight and have delicate walls, but as they increase in length they become tortuous and insinuate themselves among soil particles, the grains of sand adhering owing to the mucilaginous character of the cell walls. Owing to their intimate contact with the same, it is difficult to remove the soil. The older root hairs are continually being replaced as the root increases in length. A cross section through an older root shows that it is made up of three parts: the outer epidermis; the central axis or cylinder, containing the fibro-vascular elements; and between the two, the parenchymatous tissue.

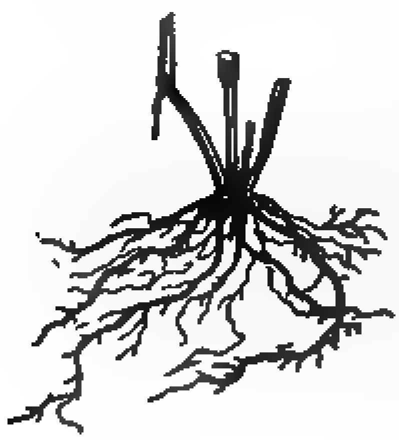


Fig. 3. Roots of Foxtail (*Setaria viridis*) (King.)

The central cylinder is bounded by the endodermis and a peripheral layer. The cells of the endodermis are without intercellular spaces, and are more or less plicate. In secondary roots the rear walls are thickened somewhat like a crescent. The bundles are arranged in a radial manner, the woody elements (xylem) occupy the center

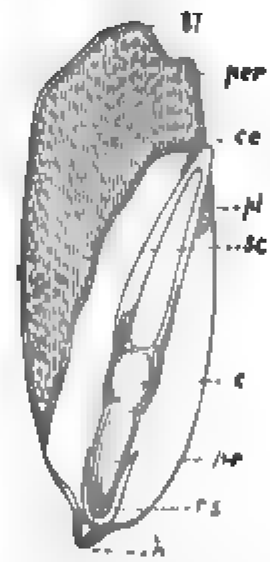


Fig. 4. Section of Maize seed. *es*, endosperm; *pl*, plumule; *sc*, scutellum; *c*, caulicle; *pr*, primary root; *h*; hilum; *rs*, root sheath. (King.)

and alternate with the soft tissue (phlœm). The woody elements consist of scalariform ducts, spiral tracheids and an annular duct.

The primary or seminal root is of short duration, and is soon replaced by the secondary, or as they are commonly called, "brace roots." These roots show conspicuous large bundles

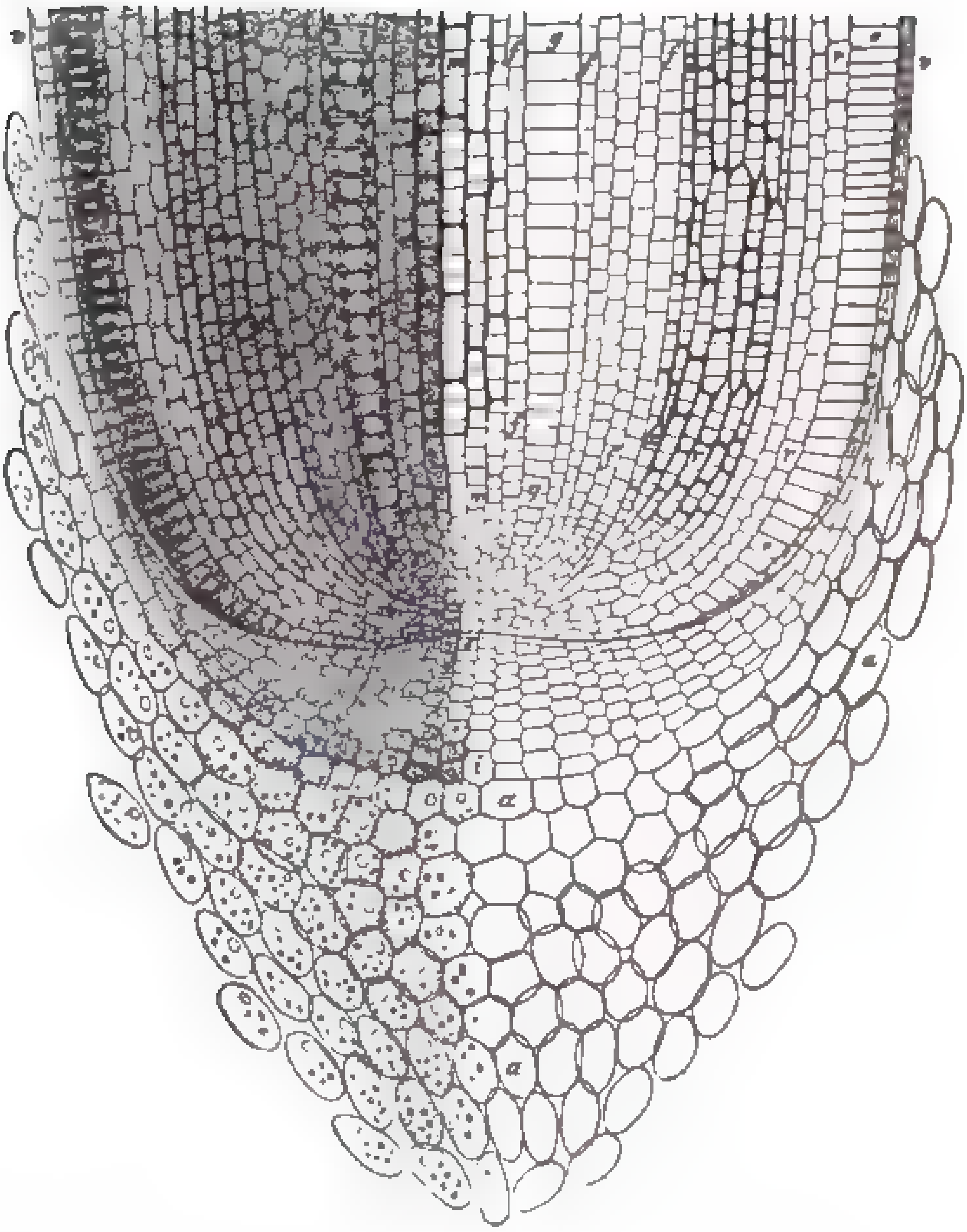


Fig. 5. Root of Maize. *a*, root-cap of loose cells; *s*, growing point; *e*, epidermis; *v*, thick walls; *m*, *g*, *f*, plerome, central cylinder; *g*, a vessel; *f*, wood; *m*, pith; *x*, *r*, cortex (Sachs.)

in which occur spiral tracheids, annular and scalariform ducts. The secondary roots arise from the nodes, and ordinarily are aerial, though some are formed soon after the seed germinates. These appear as swellings, the continued growth within causing the stem to become ruptured, and allowing the

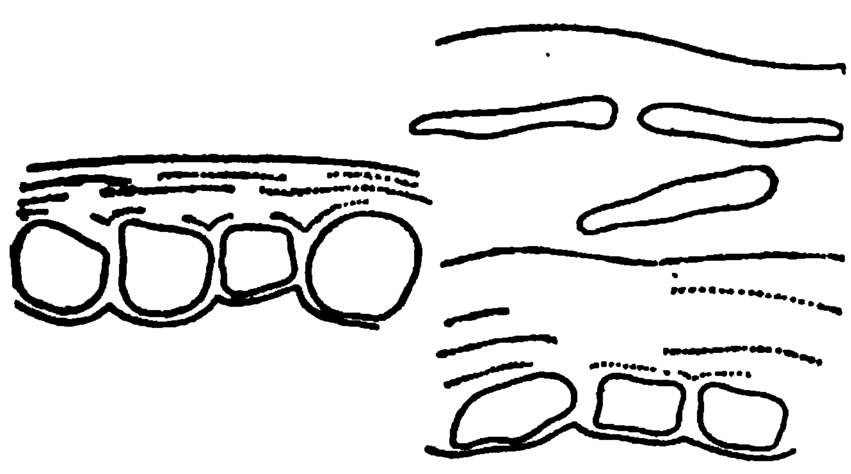


Fig. 5a. Cross-section through tip of brace root, showing epidermal cells; to the left before the addition of water; to the right after the addition of water, the outer part having expanded.

tip to emerge. It points downward and hence is positively geotropic.

Harshberger* notes that before entering the soil, gum is formed on the tip. We have often noticed this, but botanical authors have not generally noted this interesting phenomena. This thick gum is brought about by the swelling and later breaking down of the epidermal cell walls. This substance in water takes the form of mucilage, undoubtedly for the purpose of assisting the root to hold itself to the soil. The method of formation of roots has been studied by Harshberger. The developing secondary root shows before the point breaks the epidermis and hypodermis. "Three superimposed hollow cones are found immediately beneath the two outer protective layers, the outer and middle cones being separated by a cushion of parenchyma. The outer cone is composed of actively growing cells with the nucleus and nucleolus plainly visible. It corresponds evidently to the calyptrogen layer of Janczewski. The inner cones correspond to the periblem and plerome cylinders with the outer layer of the periblem as the dermatogen or proto-epidermis. The cells of the plerome, destined to form the central vascular system, are much longer than broad, the long axis anticlinal."†

Distribution of roots.—It is well known that roots have an important relation to the development of corn, especially in the manner of occurrence. The habit of the roots largely influences the amount of growth the plant can make provided other factors, sunshine and warmth are favorable.

The development of roots is largely governed by external factors, especially amount of rainfall and moisture in the soil.

In a paper read before the biological section of the American Association for the Advancement of Science, the following summary was made by the writer:

"It has been stated that not more than 10 per cent of the roots of corn enter the subsoil. Sturtevant‡ estimates as a

* Maize, l. c. 81.
† l. c. 81.
‡ Conn. Board of Agriculture. 1882: 70.

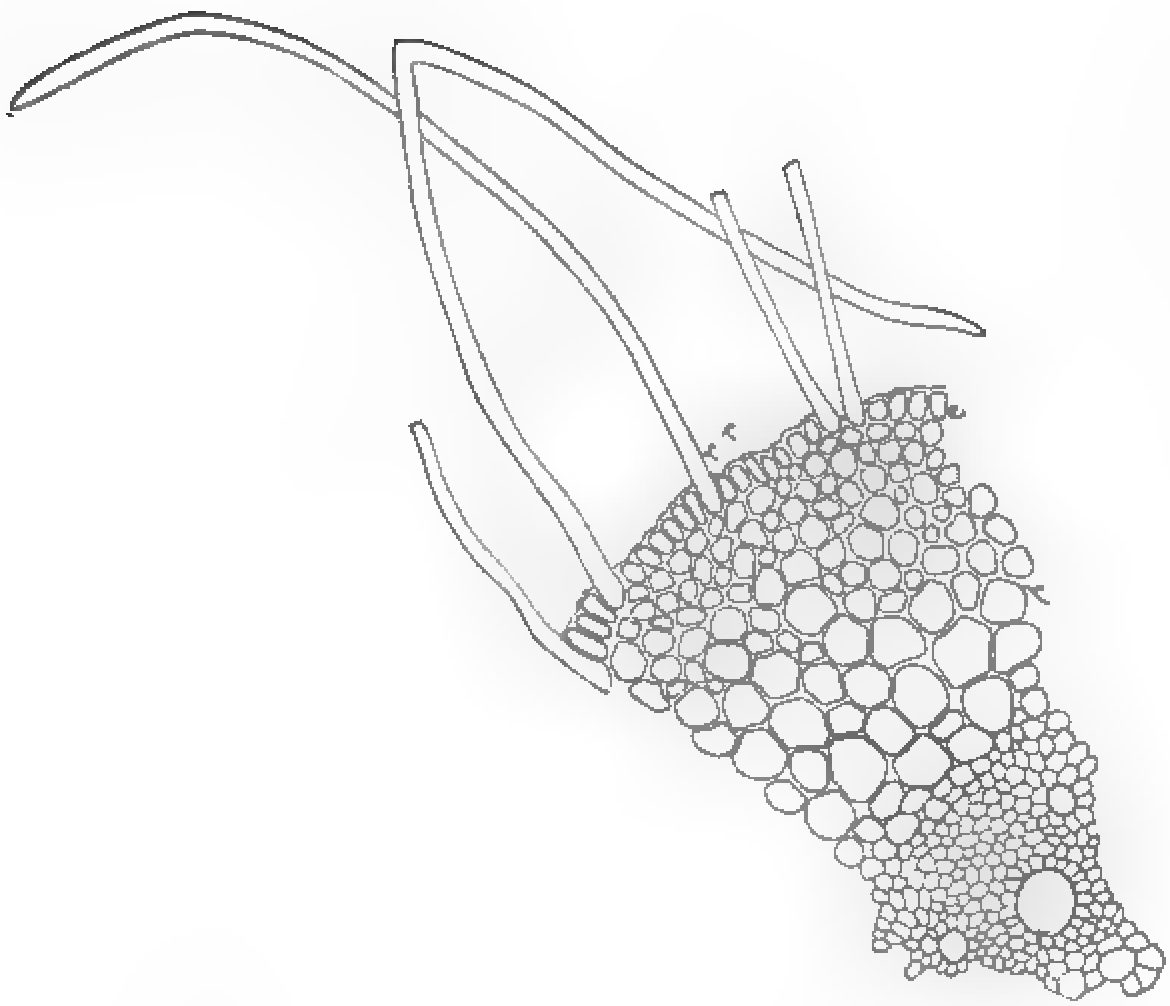


Fig. 6. Cross-section of root of corn germinated in moist chamber, showing ro hairs.

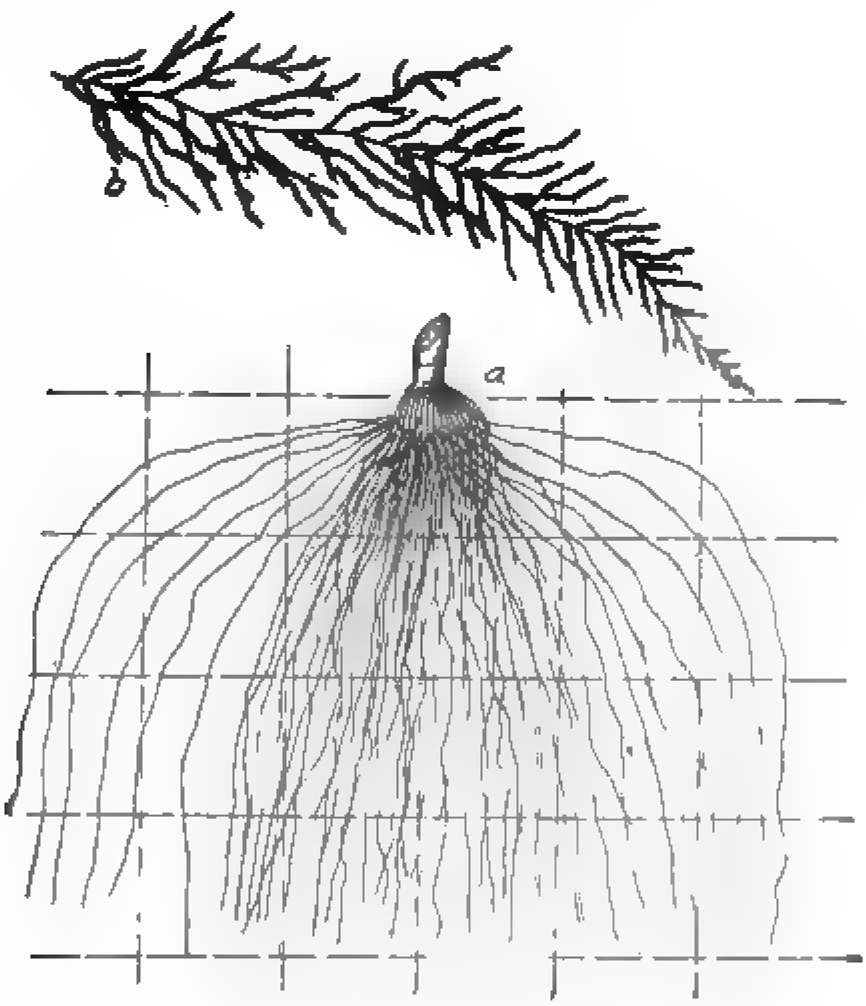


Fig. 7. The distribution of maize roots in the soil. a, general distri011tion; b, root magnified.

result of some work carried on with Gilbert that only one one-thousandth of the roots of corn enter the subsoil. Armsby also observes that in a stiff clay soil few of the roots of corn enter the subsoil. Thiel also observes that in our cultivated plants most of the fine roots which supply the plant with mineral matter occur in the upper strata. Hunt,* in commenting on some experiments made in Illinois, says: 'Two-thirds of the roots would have been broken by root pruning four inches deep; more than two-fifths would have been broken at three inches deep; and one-seventh at two inches deep.' Newman† observes that most of the roots are within four inches of the surface; these roots severed from the plant will deprive it of three-fourths of its nourishment."

Hays‡ says: "Returning to the direction or spread of the roots in the soil, those of the first whorls, say the five lower ones, start out nearly horizontally. This is in accordance with certain facts, viz: at this season of the year surface soil is warm, while the subsoil is yet cold; the upper soil is also richer in plant food and usually contains at this season an abundance of moisture. We see at 1, 2 and 3, plate I, that all the roots go nearly horizontally, and a cultivator running four to six inches deep, and the same distance from the hill, would sever most of these roots. After about the fourth week we find these primary roots changing their course, however, for having heretofore pushed outward they now grow downward, soon taking a nearly vertical direction. Not alone the roots which first grew outward, but all those now starting from the nodes above as well, take this downward course from the very beginning."

Armsby§ states as the result of some work carried on under his direction by Hickman: "Concerning the direction of the growth, a few words may be written, although the plan of the experiment did not include accurate observations and measurements upon this point. It was observed that the nodal roots, and especially those later formed, branched out horizontally from the stem for a considerable distance, and then turned downward quite rapidly. In the stiff soil in which the plants were grown, few of the roots appeared to enter far into the subsoil, which is a very stiff clay, so that in this situation

*Bull. University of Ill. Agrl. Exp. Station. 13: 427, 1891.
†Bull. Alabama Agrl. Exp. Station. 4: 1837.
‡Prairie Farmer 1887: 873. 631; Bull. Minn. Agrl. Exp. Sta., 5:
§Ann. Rep. Penn. State Coll. 1886: 97.

the corn seems to be a shallow-rooted plant, as much by reason of the obstacles which the roots encountered in growing downward, as by any habit characteristic of the plant. Other observations, to which attention will be called later, indicate that in looser soils corn roots grow to a much greater depth than was observed in this locality."

Since this above was written, King* has made a careful study of the root development of corn, from which it appears that forty-two days after planting the roots had penetrated a depth of eighteen inches. The surface roots sloped gently downward toward the center of the row, where those nearest the surface were some inches deep. When corn was three feet high the roots occupied the entire soil down to a depth of two feet.

"Here the roots are seen to occupy the entire soil down to a depth of two feet, which is the height of the cage. At this stage the surface leaders descend in a gentle curve toward the center of the row where they pass each other and lie only six inches deep.

"Just as the corn is coming into full tassel a third sample was taken which is represented in figure 10, and here it will be seen the roots have fully occupied the upper three feet of soil in the entire field. In the center of the row, too, the surface leaders have risen still higher, and a few of them are now scarcely five inches deep, though the great bulk of them are still six inches or more below the surface at the center."

Concerning the distribution of the roots of our forage grasses very little definite is known, since few experiments have been made. The roots of blue grass during the spring and early summer are more or less horizontal and these spread obliquely downward in the soil. The grass makes little growth during dry weather for the reason that the majority of the roots occur in the surface soil. The well developed rhizomes maintain its vitality. The roots of annual grasses like Setaria, *Panicum capillare*, and *P. sanguinale* are developed in a manner similar to corn.

The Stem.

Gross character.—Grass stems are always branched at the base, and occasionally in their upper portions. If the branches are all apparently at the root, the culms are said to be simple,

* Annual Rep. Wis. Agrl. Exp. Sta. 9: 113.

the visible portion above ground being unbranched. Sometimes the stems or branches stand vertically upright, when they are termed erect; they may spread a little at first, and then assume an erect position, the lowermost joints being bent or kneed; such culms are said to be geniculate at the base. The

Fig. 8. Mexican corn. Showing method of growth on grounds Iowa Agricultural college.

basal branches may lie flat upon the ground and spread more or less extensively, taking root at the usually numerous joints, and at definite points sending up erect flowering-branches, or branches bearing leaves only; such grasses are said to have a creeping habit, or are stoloniferous. Again one or more of the lowermost branches may not come to the surface at all, or

only after it has extended through the soil for a greater or less distance. These form the "creeping roots" (rhizomes) of grasses, but they are true stems or branches, for they are always distinctly jointed, and at the joints there are scale-like leaves—characters never found in true roots. The joints of these

Fig. 9. Japan millet (*Panicum crus-galli*), showing method of forming stools.

underground stems may be very short, and from each node may spring a flowering branch. So condensed may this growth be that the rhizome is entirely concealed, but in perennial grasses it is always present, and in the best turf or sward-forming grasses it is sufficiently manifest. In couch-grass, and especially in Johnson grass and cord grass, these rhizomes

are greatly developed, penetrating the soil in all directions, forming a sward that is exceedingly difficult to break.

Grass stems are usually round or cylindrical, rarely flattened, and generally hollow between the joints or nodes (solid or with pith in the Andropogons, Indian corn, sorghum and a few other grasses). The nodes, familiarly termed the joints, are the points on the culm or its branches from which the

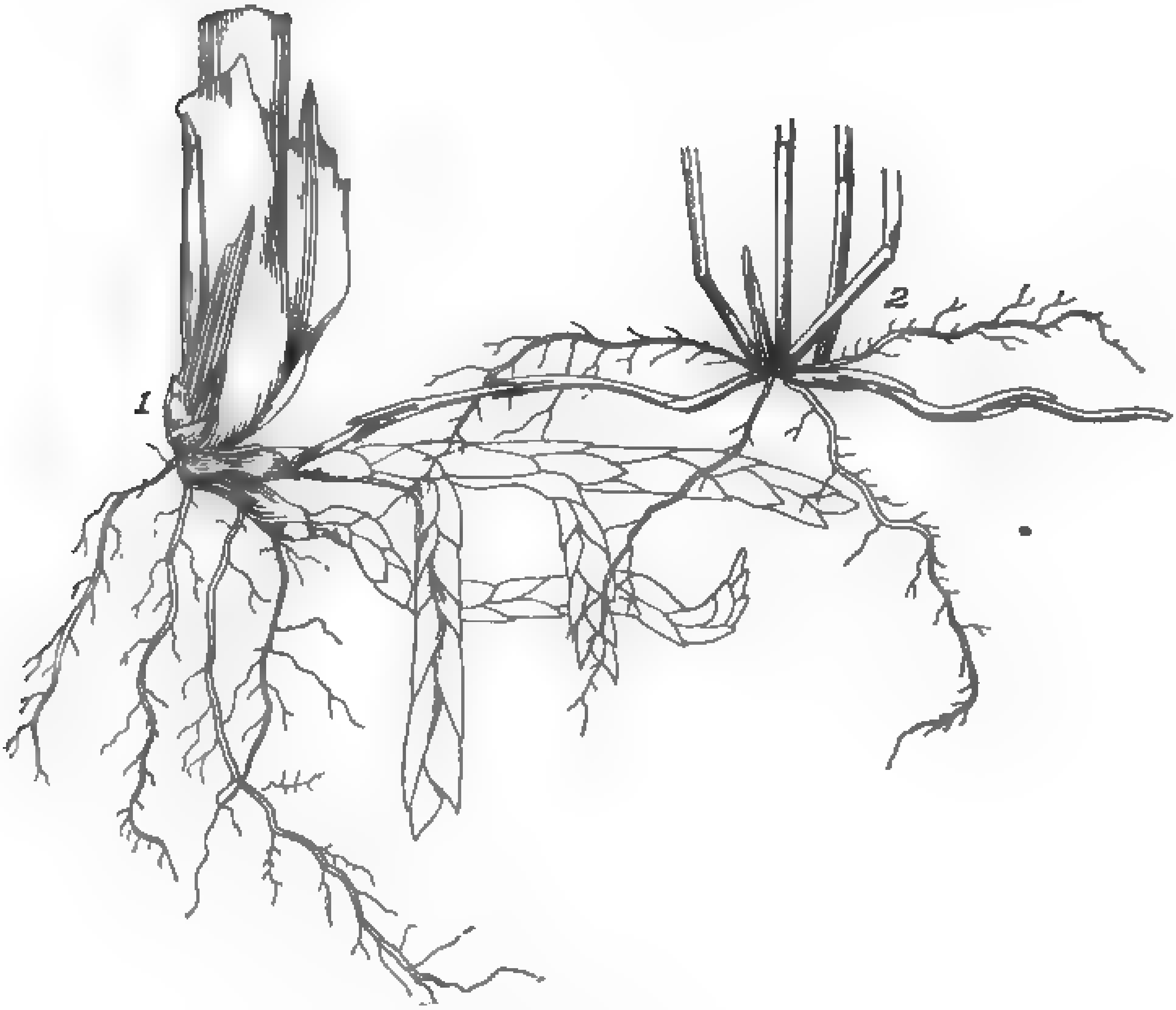


Fig. 11. Rhizomes. 1. Rootstock of slough-grass (*Spartina cynosuroides*). 2. Quack-grass (*Agropyon repens*). (King.)

leaves originate; they are usually somewhat swollen, the enlargement being either in the culm or, as is very often the case, in the basal part of the leaf-sheath. The space between two nodes is the internode. All branches, excepting those of the general inflorescence, originate in the leaf-axils, that is, within and at the base of the leaf-sheaths, and between the branch and the main axis or stem there always is a longer or shorter two-keeled prophyllm with its back tnruned towards

the main axis. The presence of this prophyllum always indicates the presence of a branch, although the branch may be very much shortened, as in the case of the true floral axis where this prophyllum is the palea.

Fig 12. Section of culm of Wild Rice (*Zizania aquatica* L.) showing fibro-vascular bundles and chambered pith. (King.)

Minute anatomy of stem.—A cross section of a culm from which the leaf sheath has been removed will show first an epidermal layer composed of thick walled cells, isodiametric in *Zizania aquatica*, but longer than wide in *Bromus mollis*. Variations occur in other genera. In a longitudinal section the epidermal cells are longer than broad. The epidermis is unbroken except for the stomata, which are not as frequent as in the leaf and sheath. The stomata connect with the loose spongy parenchyma. In Zizania and Bromus, Zea and other grasses the epidermis is followed by sclerenchyma sheath. This sheath varies in thickness in different grasses, being particularly well developed in Zizania and Zea. In some grasses like *Zizania aquatica* there are two sclerenchyma sheaths, one immediately under the epidermis, a second layer below the spongy parenchyma. Sclerenchyma is also found in connection with the bundles.

The fibro-vascular bundle is especially prominent. In pithless culms the fibro-vascular bundles are arranged, usually, in two circles; one occurs on the inside of the sclerenchyma ring, the other on the outside of it.

In species with pith, like Zizania, a first row of bundles occurs on the outer edge of the second sclerenchyma sheath. A second row of bundles occurs just underneath or a little below the sclerenchyma sheath. The remaining bundles are arranged in indistinct circles. Hackel says: "The fibro-vascular bundles run parallel in the internodes; the superficial ones join those of the lower internodes directly, the others take the form of a shallow arch bending towards the center (in culms with pith), where they pass through several internodes, and finally bend outwards to join the superficial ones. In the nodes the bundles cross and interlace and by means of small and short cross-bundles, which pass from the axillary shoots or buds towards the center. In this way arise the dia-

phragms or plates of tissue which separate the pith cavities of the internodes."

The function of the sclerenchyma is to give the plant firmness and support. It is evident that strength is obtained best

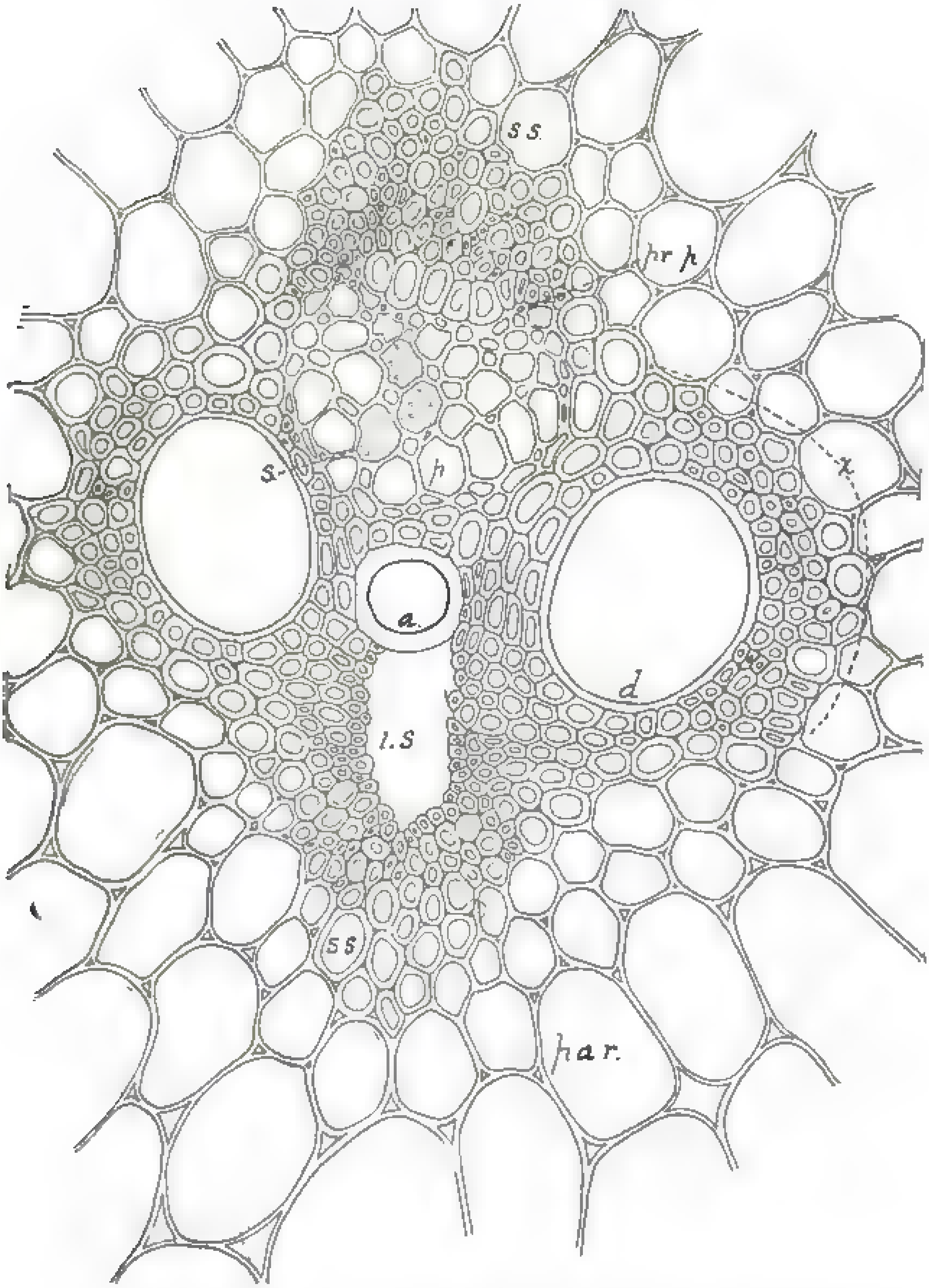


Fig. 13. Cross-section bundle of maize stem. *x*, xylem or wood; *s*, *p*, *pr*, *p*, phloem or soft bast; *s*, *p*, sieve tubes; *pr*, *p*, companion cells; *ss*, sclerids, the mechanical elements; *a*, ringed vessels; d, duct; *par*, parenchyma; *is*, intercellular space. (Combs.)

by having the sclerenchyma in close proximity to the epidermis. The peripheral bundles, including the sheath, constitute a system of compound pillars indispensable to maintain a plant in an erect position.

The fibro-vascular bundles, in addition to the thickened lignified elements may be divided into two parts: the soft bast or

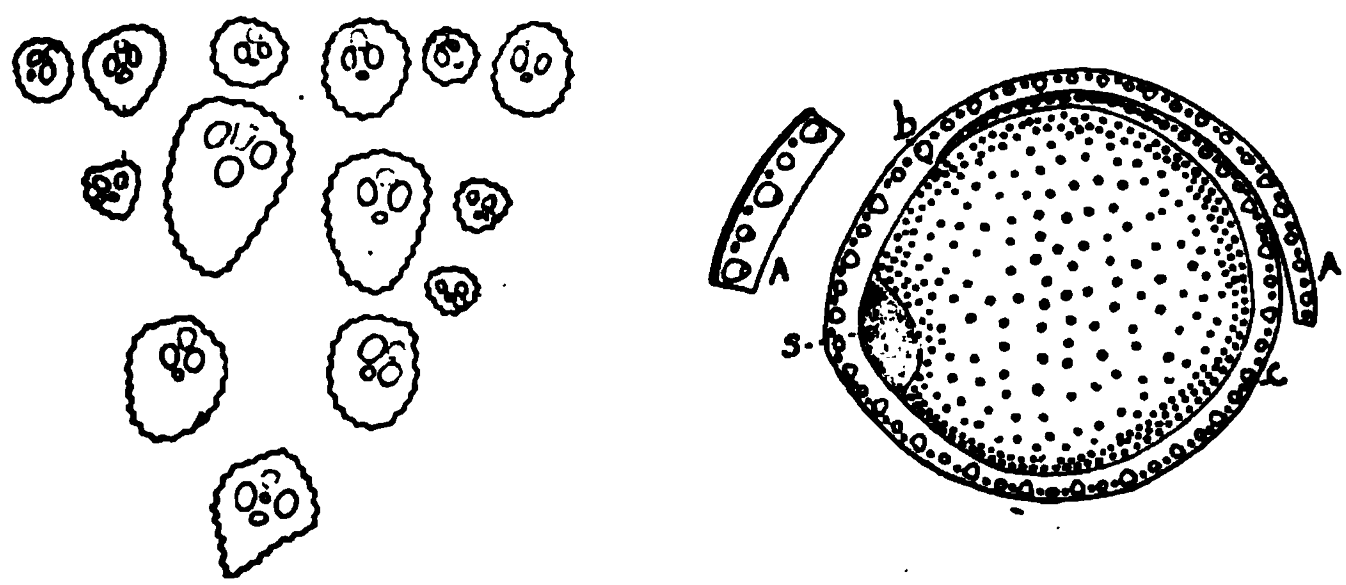


Fig. 13 A. Cross section of corn. To the right general arrangement of bundles. *a*, leaf sheath; *s*, where leaf originates. To the left bundles more magnified.

phloem which consists of the sieve tubes and the companion cells; second, the xylem which consists of several pitted vessels and a spiral duct towards the center and below an intercellular passage; this has resulted from the breaking down of an old ringed vessel.

Theodore Holm, in an interesting review of an extended paper on structure of rhizomes states that, "Although the function of the stolons in the Gramineæ is nearly the same, being at once reservoirs of nutritive matters and for the service of the vegetable propagation, some differences have also been observed in the interior structure."

It has been shown from the numerous intergradations between the underground stolons and the shoots above ground, that the organizations of the stolon depend upon a modification of the above-ground shoot. The structure of the shoot above ground is well marked by the position of the mechanical tissue, which is either truly sub-epidermal or more or less distinctly sub-cortical, the bark being as a rule not very strongly developed. But there is a large series of modifications between the form and those derived from such shoots as show a tendency to replace the stolons.

Fig. 14. Leaves of grasses. 1, Blue stem (*Andropogon provincialis*, Lam.); 2, *Poa pratensis* L.; 3, *Hordeum jubatum* L.; 4, *Andropogon scoparius* Michx; 5, *Paspalum ciliatifolium* Michx; 6, *Zea mays* L. (King.)

The Leaves.

Grosscharacter.—The leaves of grasses have two distinct parts: the sheath and the blade. The sheath, or basal portion, usually closely surrounds the stem, and is split or open upon the side opposite the blade, or is entire, then forming a closed cylindrical sheath (vagina) about the stem. When split, the free edges usually overlap each other. At the top of the leaf-sheath, at the point where the blade originates, there is upon the inside usually a thin and delicate prolongation, often very short, called the ligule. Sometimes the ligule takes the form of a fringe of hairs. The leaf-blade is generally narrow, usually many times longer than broad, with nearly parallel edges. Such leaves are called linear. From this form the leaves may vary to lanceolate or ovate in outline. Sometimes the narrow leaves have their edges rolled inward, when they are said to be involute. Occasionally the leaf-blade is very short, and sometimes it is wanting altogether, the sheath alone remaining. As to the surfaces of the leaves and sheaths, they may be smooth or rough, or more or less hairy. The terms used here are those of general application.

The position of the leaves on the stem is to be noted as affording a ready character for distinguishing grasses from the nearly allied grass-like sedges. Starting with any leaf on the stem of a grass, the next leaf above will be exactly on the opposite side of the stem; while the next or second leaf above will stand directly over the starting point. Such an arrangement is called distichous or two-ranked; *i. e.*, in counting two leaves from the first we pass completely around the stem. In sedges the leaf arrangement is three-ranked; it is the third leaf from the first which stands directly above the first.

The mature blades often show torsion, being either twisted to the left, right, or in both directions; being twisted in one direction above and the other below. Certain grasses are turned 180 degrees at the base so that the upper and lower sides are reversed. In this case the stomata occur on the original upper side. This is true of grasses growing in the woods and is brought about through the influence of light.

Minute anatomy.—The fibro-vascular bundles are separate or they unite to form a strong mid-rib as in corn. The fibro-vascular bundles of the leaf consist of the soft bast phlœm and woody elements, the xylem. The bundle is protected on each side by sclerenchyma, true at least of the primary veins; this

gives the leaf additional strength. The number and character of the bundles varies in different species of grasses. In *Sporobolus heterolepis*, Miss Emma Sirrine and Mrs. Hansen found that the mid-rib consists of a single mestome bundle.*

This bundle is surrounded on the upper side by chlorophyll bearing parenchyma, while the lower side contains stereome. The mestome bundles to the right and left of the mid-nerve are entirely closed, that is entirely surrounded by chlorophyll bearing parenchyma. There are three types of mestome bundles in this species as follows, the mid-nerve with stereome on the lower side which is in contact with leptome or the second with stereome on lower and upper sides in contact with leptome, and third, entirely closed. These alternate with those having stereome on upper and lower surfaces. The leaves terminate with one closed mestome bundle. The uncolored parenchyma of the leaf is in immediate contact with the stereome. This is most conspicuous near the mid-nerve. The chlorophyll parenchyma may be divided into two parts, first, large parenchyma cells, which surround the bundles, and, second, to the outside of these, elongated cells in one or more rows. This species represents a type intermediate between plants adapted to very dry climates and one adapted to somewhat moister conditions. Mrs. Hansen has described the structure of a typical xerophytic plant, *Festucu tenella.*† In this species the mestome bundles number twelve and are of three types. First, primary, open both on inferior and superior surfaces of leaf, *i. e.*, those which have hadrome and leptome respectively in contact with stereome, either in direct contact or are separated from it by several rows of thin-walled parenchyma cells. Second, the secondary type. These are entirely surrounded by chlorophyll-bearing parenchyma. Third, intermediate type. These open inferiorly. Only one bundle of primary type occurs and this is in the mid-nerve. The leptome and hadrome are in direct contact with each other. The leptome is separated from the stereome by thin-walled parenchyma cells. A considerable development of thin-walled parenchyma cells occurs above the mestome

* Some anatomical studies of leaves of Sporobolus and Panicum. Proc. Ia. Acad. Sci., Des Moines. 3: 151. *pl. 6. f. 1-3.* 1896. Contr. Bot. Dept. Ia. St. Coll. Agrl. Mechanic Arts. 1.

† A comparative study of the leaves of Lolium, Festuca, and Bromus. Proc. Ia. Acad. Sci., Des Moines. 4: 127. 1897. Contr. Bot. Dept. Ia. St. Coll. Agrl. and Mechanic Arts. 4.

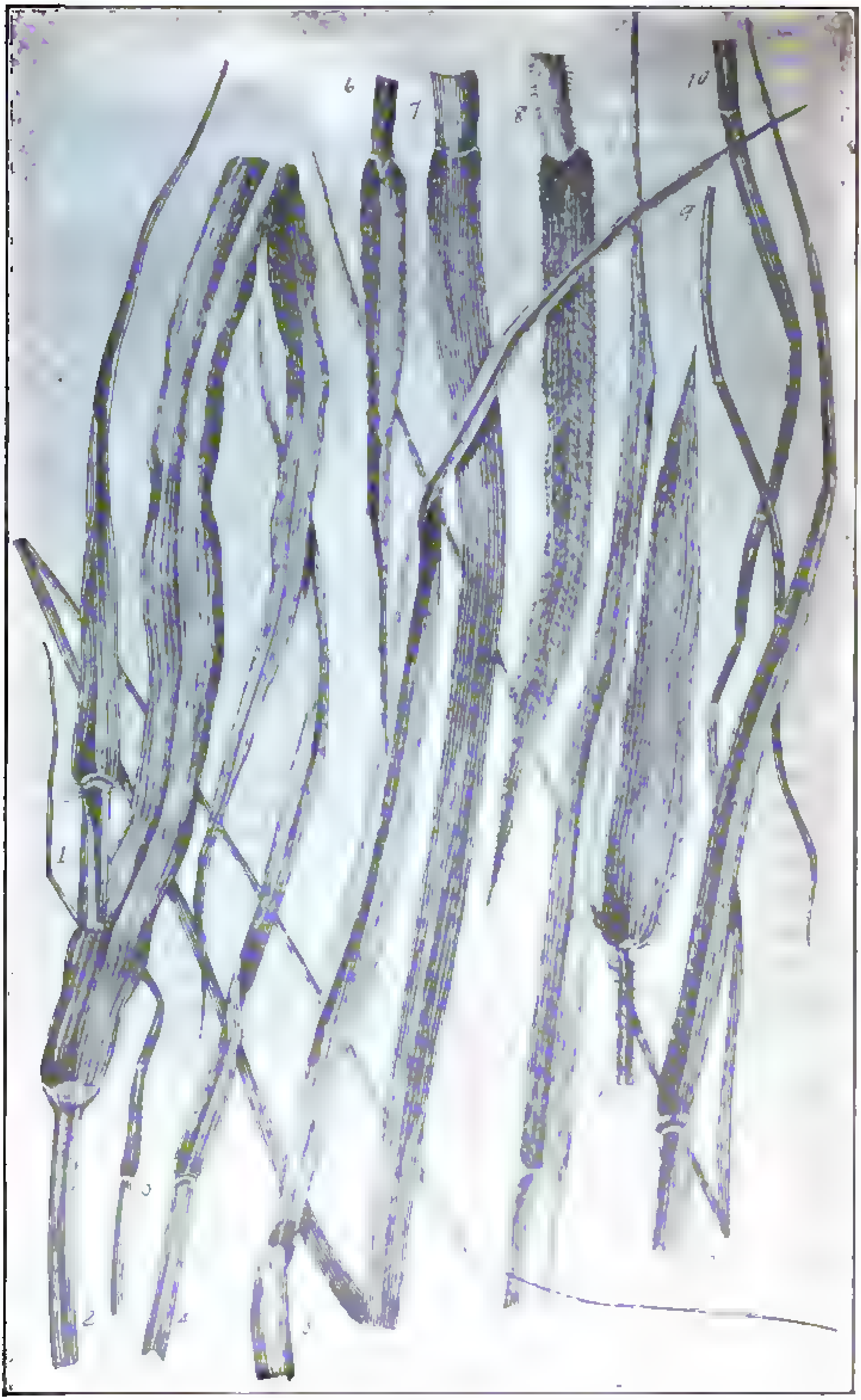


Fig. 15. Leaves of grasses. *1*, Stink grass *Eragrostis major* Host; 2, *Setaria italica*, Kunth; *3*, *Sporobolus vaginæflorus*; *4*, *Muhlenbergia Mexicana*; *5*, *Andropogon nutans*; *6*, *Phleum pratense*, L.; 7, *Spartina* [illegible]'s Willd; *8*, *Panicum capillare*, L.; *9*, *Aristida basiramea*; *10*, *Sporobolus heterolepis*, Gray; *11*, *Elymus* [illegible] *Panicum scribnerianum* Nash.; *14*, *Sporobolus longifolius*. (King.)

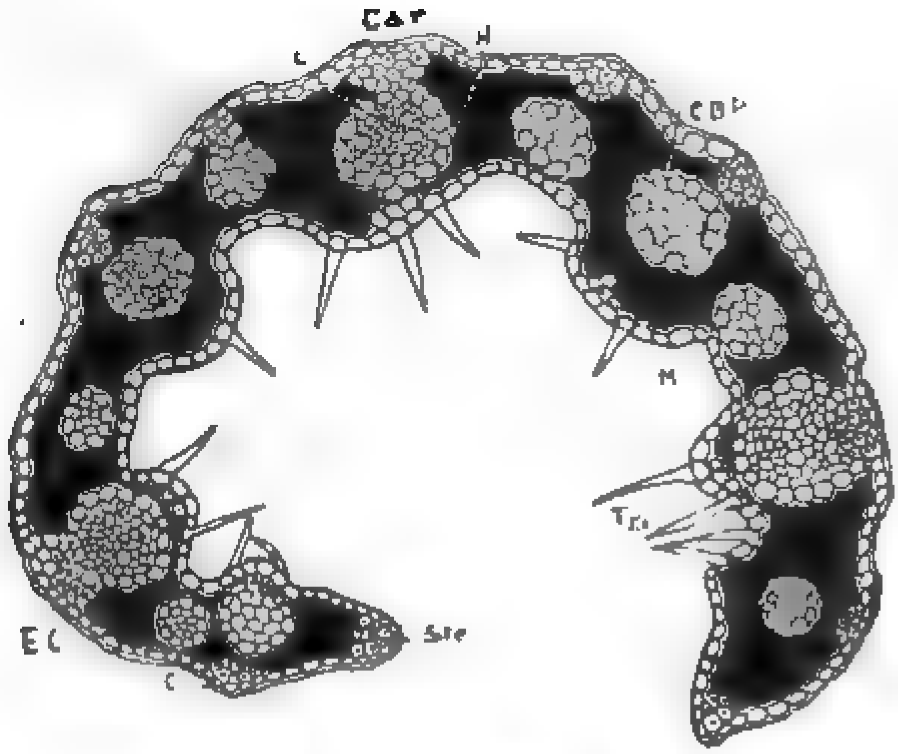


Fig. 16. Section of leaf of *Festuca tenella* Willd. *Car*, mid-nerve; *CBP*, chlorophyll bearing parenchyma; *M*, mestome bundle; *EC*, epidermal cells; *Ste*, stereome; *Tri*, trichome; *L*, leptome; *H*, hadrome. (Hansen and King.)

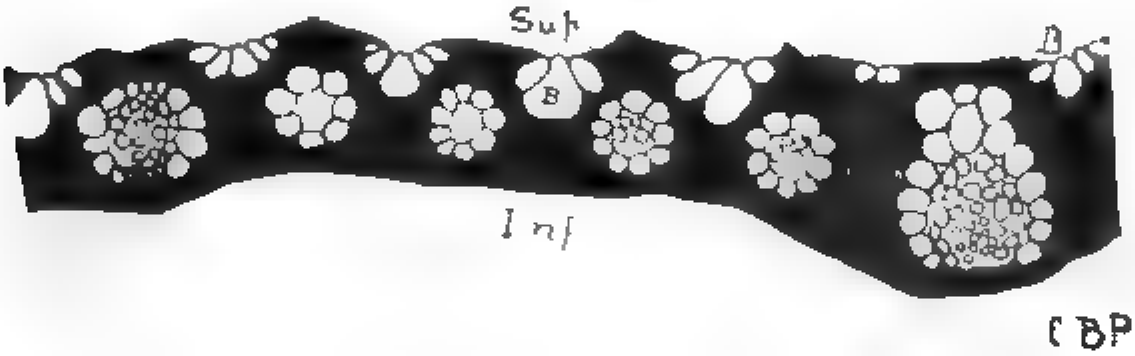


Fig. 17. Section of leaf of *Eragrostis major* Host. *Sup*, superior surface; *Inf*, inferior surface; *B*, bulliform cells; *CBP*, chlorophyll bearing parenchyma. (Ball.)

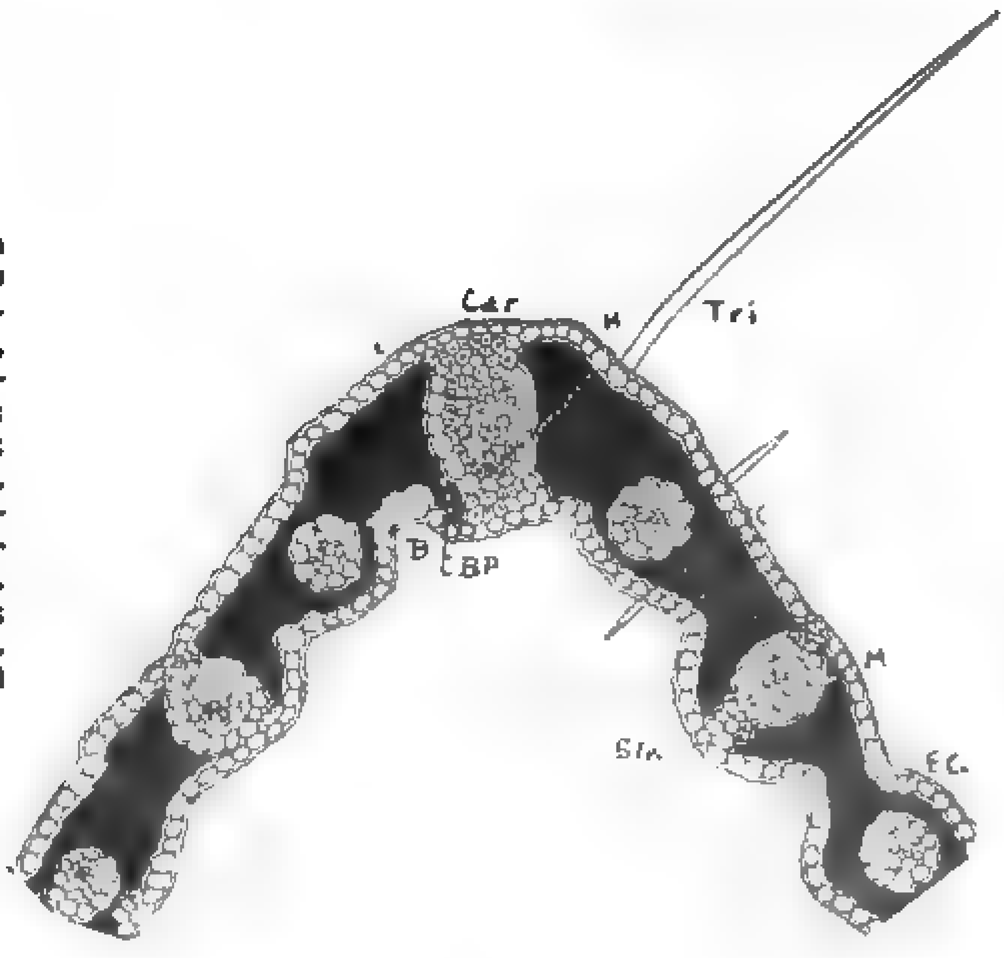


Fig. 18. Section of leaf of *Bromus mollis*. *B*, bulliform cells; *CBP*, chlorophyll bearing parenchyma; *Car*, mid-nerve; *Tri*, trichome; *L*, leptome; *H*, hadrome; *EC*, epidermal cells; *M*, mestome bundle; *Ste*, stereome. (Sirrine and King.)

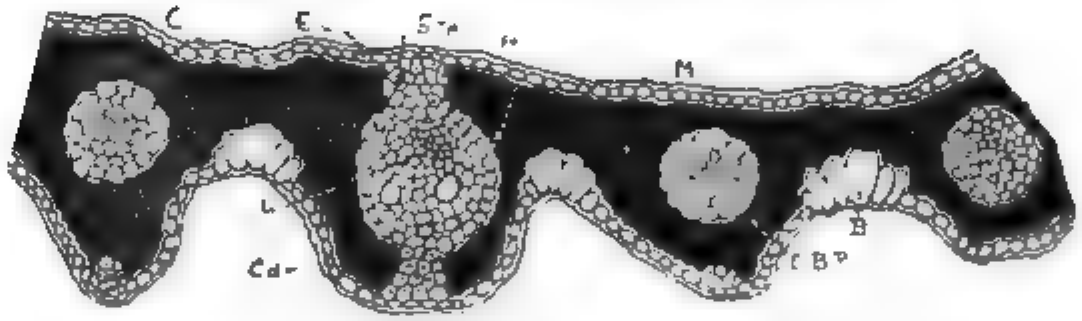
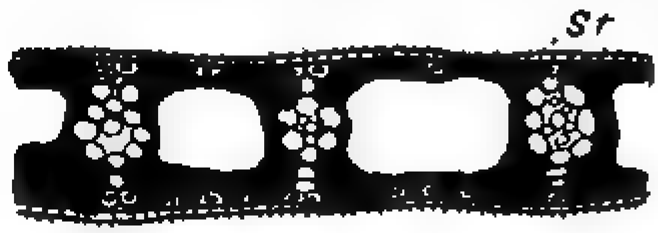
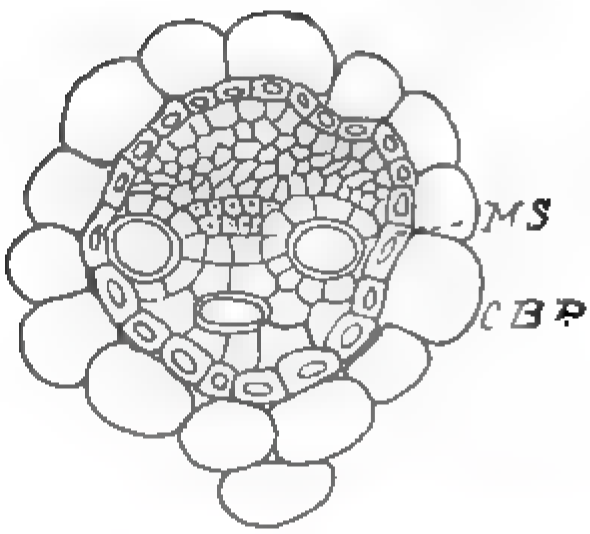


Fig. 19. a Section of leaf of *Festuca elatior* var. *pratensis* Hackel· *Car*, mid-nerve; *CBP*, chlorophyll-bearing parenchyma; *B*, bulliform cells; *M*, mestome bundle, *L*, leptome; *H*, hadrome;. *Ste*, stereome; *EC*, epidermal cells. (Pammel and King.)



c. Cross section. From leaf of *Pleuropogon californicum*. *MS*, mestome sheath; *CBP*, chlorophyll bearing parenchyma. (From Holm.)



b. Section of leaf of *Pleuropogon californicum* Nees. . *St*, stereome. (From Holm.)

Fig. 20. Section of leaf of *Festuca elatior* var. *pratensis* Hackel. *L*, leptome; *H*, hadrome; *Ste*, stereome. (Pammel and King)

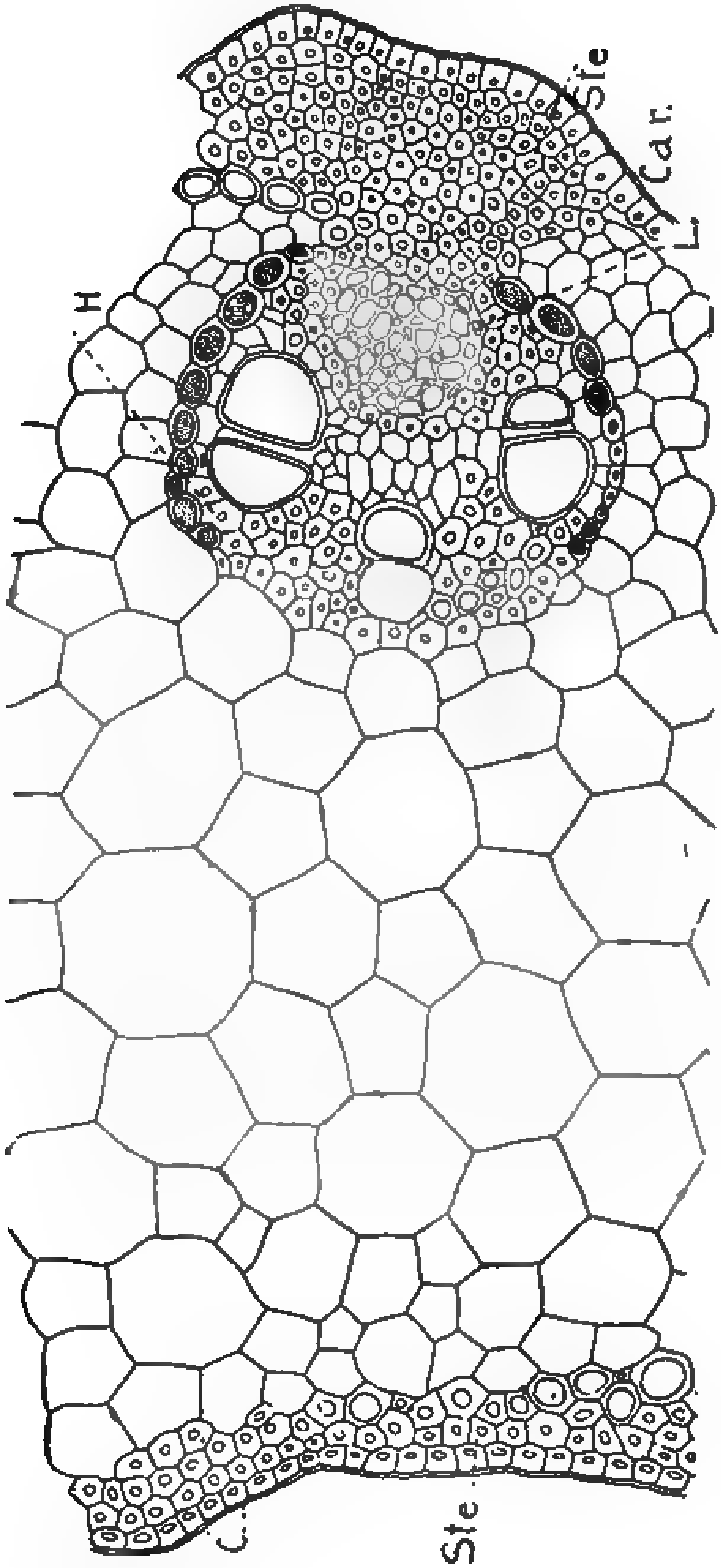


Fig. 21. Section of leaf of *Andropogon nutans* L. *Car*, mid-nerve; *L*, leptome; *H*, hadrome; *Ste*, stereome; *C*, cuticle. (Weaver and King.)

bundles of the mid-nerve. Two bundles of the third type occur near the margin of the leaf. The cells separating the leptome from the stereome are in this case somewhat thicker-walled than those in the mid-nerve.

The mestome bundles of second type are of two sizes, the largest ones having leptome and hadrome poorly developed, and the smallest having no thick-walled cells.

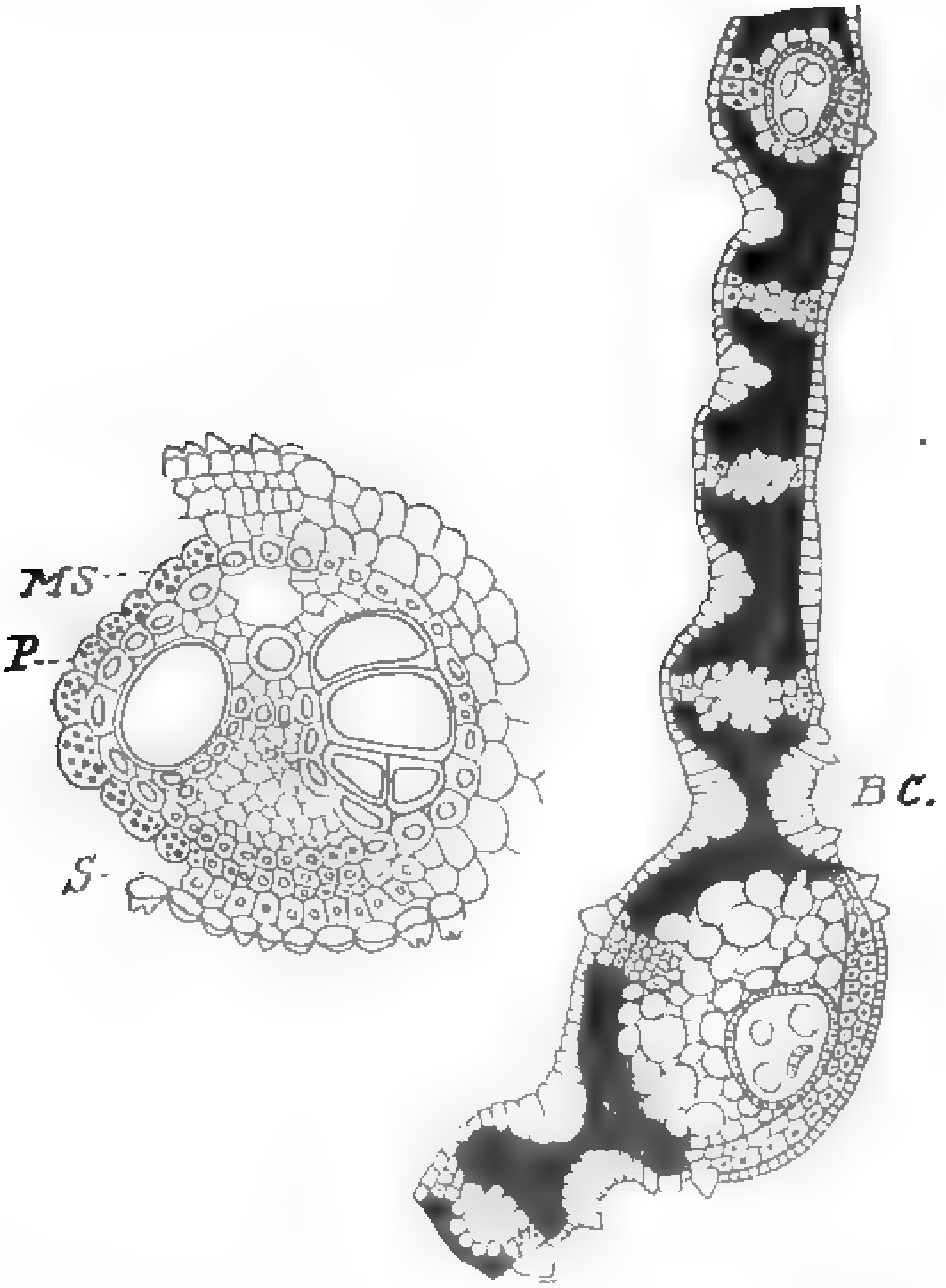


Fig. 23. Section of leaf of *Leersia oryzoides* Schwartz. *BC*, bulliform cells; portion of mid-rib in section; *MS*, mestome sheath; *P*, parenchyma; *S*, sclerotic cells. (Holm.)

The thin-walled parenchyma, with its inner closed sheath does not differ from that of *Festuca pratensis* and *Lolium perenne*. Stereome seems to be more strongly developed in this species than in *Festuca elatior*, var. *pratensis* and *Lolium perenne*. It

occurs on the margin of the leaf, and also on inferior surfaces of all bundles of the first and third types, and on inferior surfaces of all large bundles of the secondary type. Mesophyll occupies a small area in this species since the mestome bundles are close together.

Fig. 26. Section of leaf of *Festuca tenella* Willd. *L*, leptome; *H*, hadrome; *CB.P*, chlorophyll bearing parenchyma; *Ste*, stereome; *EC*, epidermal cells; *C*, cuticle. (Sirrine and King.)

Mr. Theo. Holm has described the anatomical characters of *Distichlis spicata*† a grass adapted to halophytic conditions,

† A study of some Anatomical Characters of North American Gramineæ III. Bot. Gazette. 16: 275. *pl* 23. *f*. 1-3. 1891 Miss E. L. Ogden has likewise studied the leaf structure of Jouvea and of *Eragrostis obtusiflora*. Bull Div. Agros. U. S. Dept. Agrl. 8: 12-20. *pl*. 9.

and in many respects similar to the species described above. The stereome of the superior face is widely separated from the mestome bundles by the parenchyma. In *Pleuropogon californicum* there is a distinct mestome sheath surrounding the bundles and the walls are thick. The leptome and hadrome are separated from each other by two layers of thick-walled

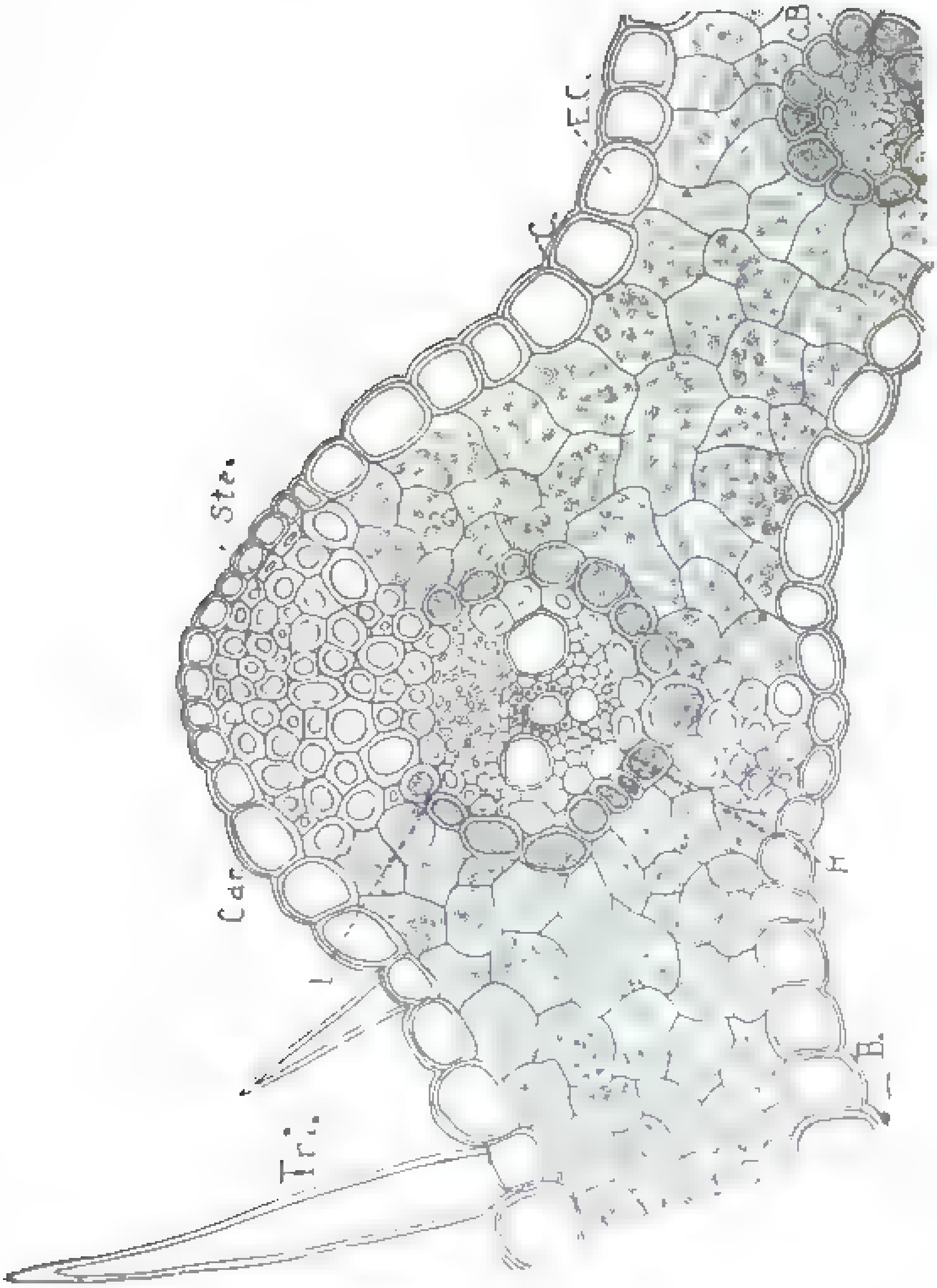


Fig. 31. Section of leaf of *Bromus mollis*. *Car*, mid-nerve; *L*, leptome; *H*, hadrome; *B*, bulliform cells; *Ste*, stereome; *CB*, chlorophyll bearing parenchyma; *EC*, epidermal cells; *Tri*, trichome. (Sirrine and King.)

parenchyma cells. In the large bundles stereome occurs above and below. They are separated from the parenchyma sheath by a few colorless cells. It may be interesting to compare the leaf structure of xerophytic and mesophytic

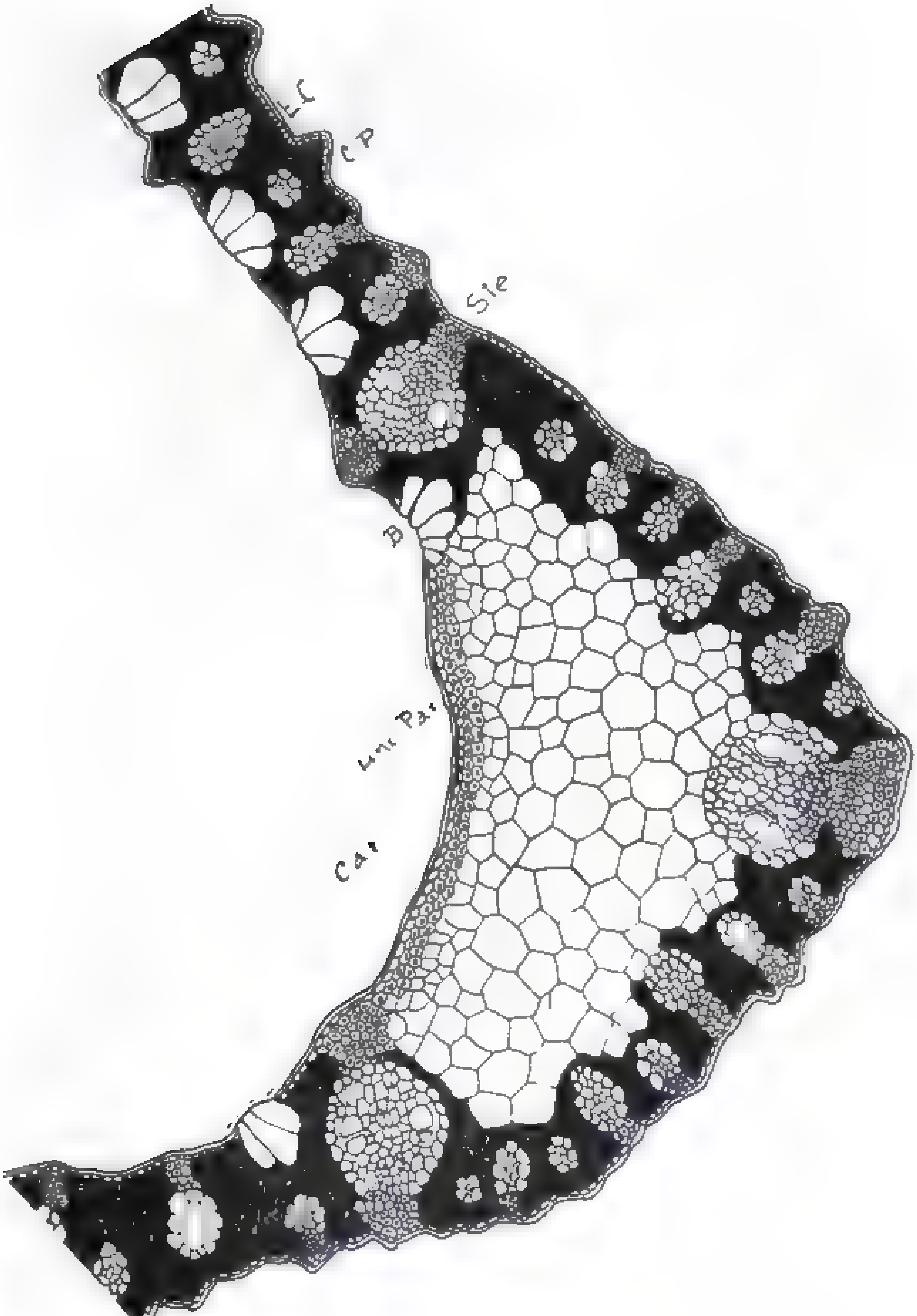


Fig. 25. Section of leaf of *Andropogon nutans*. *Car*, mid-nerve; *Unc. Par*, uncolored parenchyma; *B*, bulliform cells; *Ste*, stereome; *EC*, epidermal cells; *CP*, conical point. (Weaver and King.)

plants, belonging to the same genus. Miss Ogden‡ describes the anatomical character of the *Eragrostis obtusiflora* thus:

‡ l. c. 17.

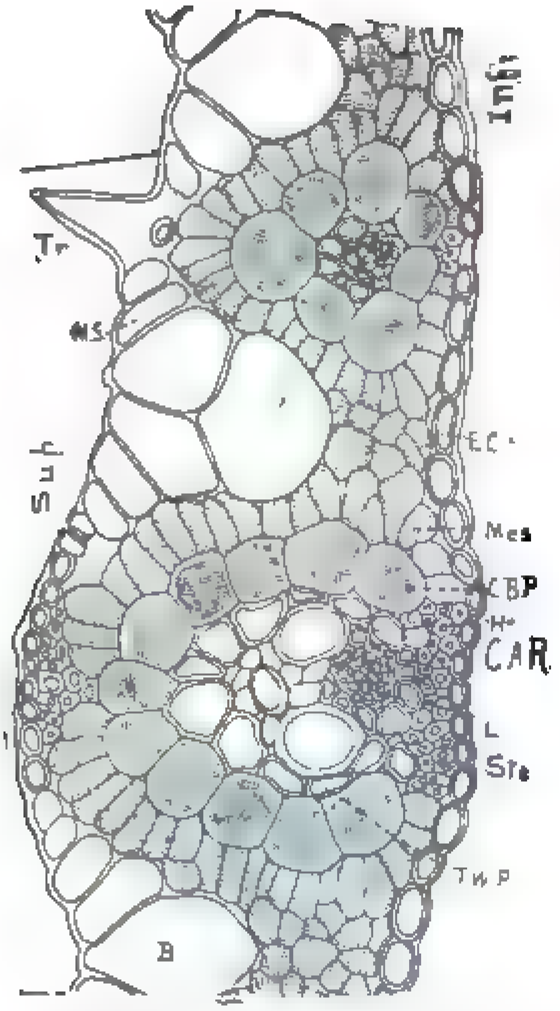


Fig. 26. Section of leaf of *Eragrostis purshii* Schrad. *Sup*, superior surface; *Inf*, inferior surface; *Car*, mid-nerve; *L*, leptome; *H*, hadrome; *St*, sterome; *MS*, mestome sheath; *Tr*, trichome; *B*, bulliform cells, *Mes*, mesophyll; *EC*, epidermal cells; *C. B. P.*, chlorophyll bearing parenchyma. (Ball.)

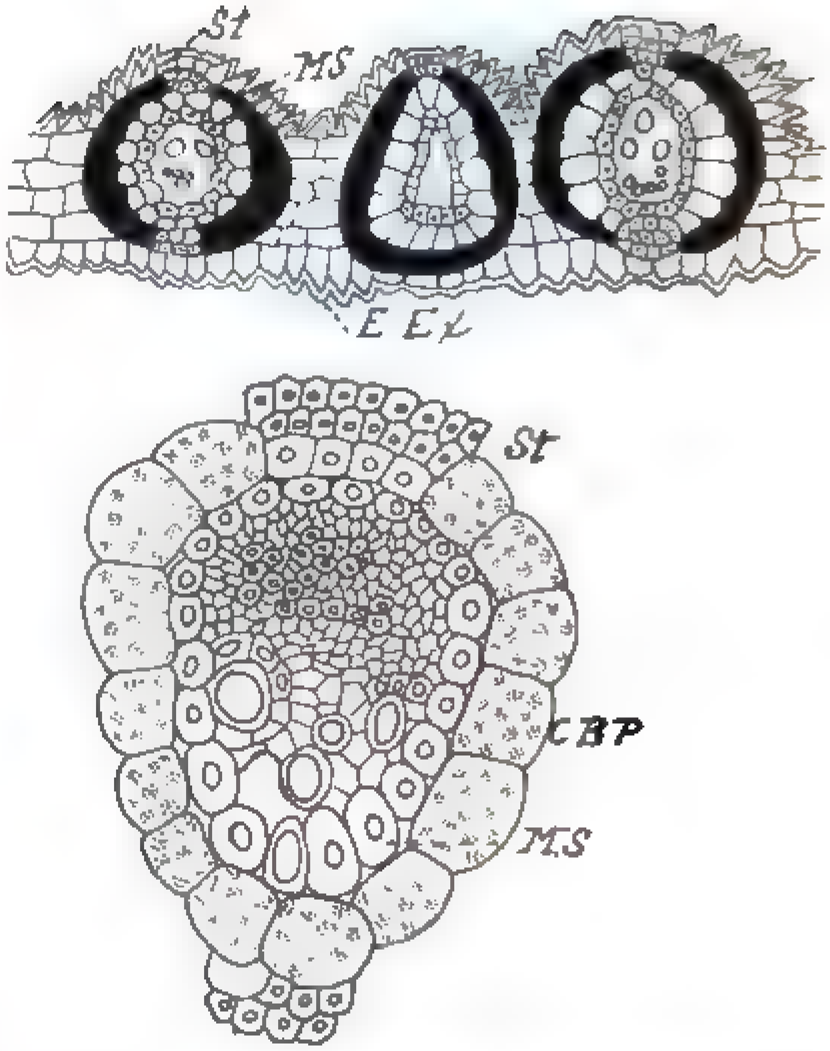


Fig. 27. *Distichlis maritima* Raf; *M S*, mestome sheath; *St*, stereome; *E. Ex* epidermal expansions. (Holm.)
Section of bundle shown below *MS*, mestome sheath; *St*, stereome; *C. B. P.*, chlorophyll bearing parenchyma. (Holm.)

"The secondary bundles differ in the marked line between xylem and phloem and also in the nature of the sheath. This consist of a single row of cells. Below and above the bundles these have relatively smaller cavities and thicker walls than the corresponding cells of *Jouvea pilosa*, but frequently on either side of the bundle there occurs one cell much larger than the others, of more angular shape, and in almost any section taken at random a transverse pitted wall is conspicuous. The two uppermost cells of the inner chlorophyll-bearing ring are at least twice as large as the other cells of the ring, and are usually wedge-shaped with the narrow end turned towards the bundle."

Mr. C. R. Ball,‖ in an interesting study of the leaves of several species of Eragrostis, well describes the mestome bundles of *Eragrostis purshii*, which number twenty-one. Sixteen belong

‖An anatomical study of the leaves of Eragrostis. Proc. Ia. Acad. Sci., 4: 140-141, 1897. *pl. 7. f. 2, 3 and 4; pl. 9. f. 12.* Contr. Bot. Dept. Ia. St. Coll. Agrl. and Mechanic Arts, 4.

to the secondary and five are intermediate. "In the secondary bundles (veins 3) the chlorophyll-bearing parenchyma sheath is nearly round in outline and composed of seven or eight subcircular cells. Hadrome, leptome and thick-walled parenchyma are not so well developed as in the preceding species. The intermediate bundles (mid-nerve and veins 2), five in number, are open below. Hadrome, leptome, and thick-walled parenchyma are well developed, the latter especially so. The chlorophyll-bearing parenchyma sheath is composed of from ten to fifteen cells. The mestome sheath is continuous above and sometimes below the secondary bundles, but is interrupted by sterome above the intermediate type. The mid-nerve is but little enlarged and not easily distinguished from vein 2 except by its position. Stereome is present in quantities both above and below the intermediate bundles and occurs in small groups of three or four cells in the secondary bundles. The mesophyll passes beneath some of the secondary bundles as a single layer of cells."

In Mr. Ball's study of *Eragrostis pectinacea*, which is *xerophytic* in its nature, a very striking chlorophyll parenchyma sheath occurs near the secondary bundles. "It is distinctly triangular in outline, with the apex directed towards the superior surface. The lateral cells are elongated transversely to the section, and the inferior or basal cells are small and nearly round. Hadrome and leptome and thick-walled parenchyma are well developed."

We find a well marked type of bundle structure of leaf in some of the mesophytic grasses represented by *Festuca elatior* which has been described by Mrs. Hansen.* "The number of mestome bundles in a single cross-section in middle of leaf is twenty-four, and are not so close as in Lolium. There are three types: First, primary type, open on inferior and superior sides. Second, secondary type, those that are entirely closed, and these are most numerous. Third, the intermediate type, which are open only on superior side. The bundles of secondary type are most numerous. Three of the closed bundles occur near the margin of leaf. One bundle of the primary type is found next to the closed bundles. The third type is found to the left of mestome bundle of mid-nerve, and to the right of mid-nerve is found a mestome bundle of second type. One primary mestome bundle occurs in mid-nerve. In the

*l. c. 128: *pl. 9, f. 1. pl. 11, f. 9.*

mid-nerve, leptome and hadrome are well developed. The pitted vessels are large. Stereome is well developed on inferior and superior surfaces of the bundles. In the mid-nerve, leptome and hadrome are separated from each other by thick-walled cells. The cells in leptome are somewhat more thick-walled than in hadrome."

Mr. C. B. Weaver's study* of *Andropogon provincialis* shows the presence of four types of bundles, viz.: first, mid-nerve; second, entirely closed; third, open, and fourth, larger secondary bundles with stereome both above and below.

"The mid-nerve consists of three large bundles open above and below. The central bundle is but little larger than the secondary bundles. In the hadrome occur the conspicuous pitted and spiral ducts. The chlorophyll-bearing parenchyma cells surrounding the larger bundles are not as conspicuous as those of the smaller mestome bundles. The stereome above the mid-nerve is well developed and is wider than the middle larger bundle; while opposite on the lower side of the leaf occur but few stereome cells, and these latter are in direct contact with the epidermal cells. The cells composing the leptome portion of the mid-nerve bundle are uniform in size. The uncolored parenchyma cells which occur below and to the side of the mid-nerve bundle, are large. These cells are in contact with the three large bundles of mid-nerve. The smaller mestome bundles on either side of the mid-nerve occur close together. The chlorophyll-bearing parenchyma cells surrounding these are conspicuous. These bundles are not uniform in number on both sides the mid-rib, which goes to show that the development of the leaf is unequal. On each side of the mid-nerve occur four of the larger secondary bundles. The edges of the leaf are provided with stereome. The stereome about the cells varies in the number of cells. The cells of the mesophyll occur as dense masses with numerous intercellular spaces. They vary in shape from elongated to spherical. An occasional small trichome may be seen."

It may be interesting to compare the above structure with that of a typical woodland grass, and for that purpose we may take *Bromus breviaristatus*. According to the researches of Miss Emma Sirrine,† the mestome bundles number forty-one.

*An anatomical study of the leaves of some species of the genus Andropogon. Proc. Ia. Acad. Sci, Des Moines. 4: 132, 1897. Contr. Bot. Dept. Ia. St. Coll. Agrl. and Mechanic Arts. 4.

†A study of the leaf anatomy of some species of the genus Bromus. Proc. Ia. Acad. Sci., Des Moines. 4: 123. *pl. 4, f. 1; pl. 7, f. 7*, 1897. Contr. Bot. Dept., Ia. St. Coll. Agrl. and Mechanic Arts, 4.

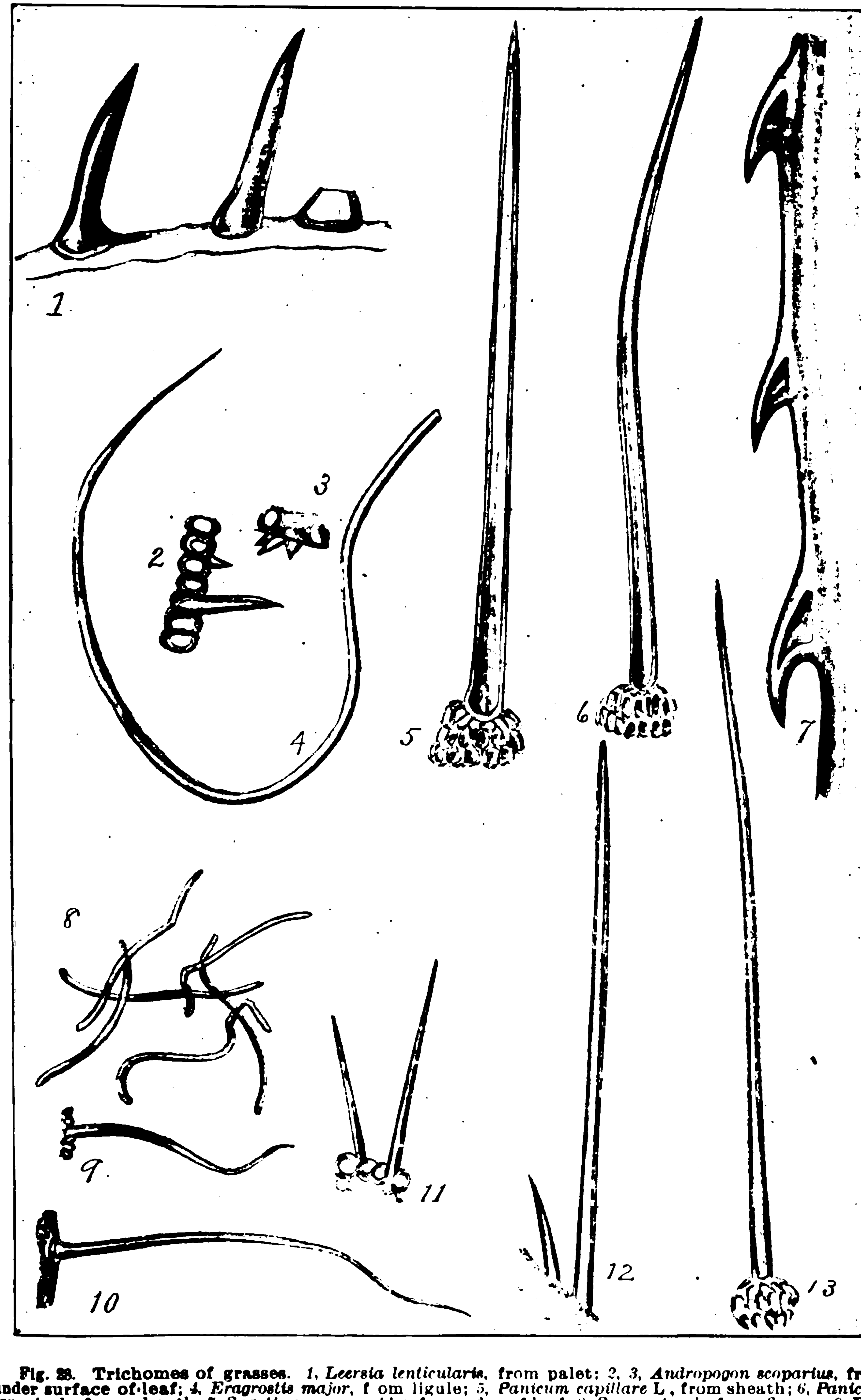


Fig. 28. Trichomes of grasses. *1*, *Leersia lenticularis*, from palet; *2*, *3*, *Andropogon scoparius*, from under surface of leaf; *4*, *Eragrostis major*, f om ligule; *5*, *Panicum capillare* L., from sheath; *6*, *Panicum sanguinale*, from sheath; *7*, *Spartina cynosuroides*, from edge of leaf; *8*, *Poa pratensis*, from fl wer; *9*, *Bromus asper*, from under surface of leaf; *10*, *Bromus ciliatus*, from sheath; *11*, *B. mollis*, from under surface of leaf; *12*, *Andropogon provincialis*, from rachis; *13*, *Bouteloua racemosa* Lag, from leaf-blade. (King)

The primary bundles open on both inferior and superior surfaces. Leptome is in direct contact with stereome. The hadrome is separated from it by corlorless parenchyma. Midnerve consists of only one bundle, and with the exception of size, the large amount of stereome and colorless parenchyma is the same as that of species adapted to open ground.

The colorless parenchyma occurs beneath all primary bundles, while a sheath encloses all the bundles. Stereome is abundant on both inferior and superior surfaces of the intermediate bundles. Mesophyll surrounds all the secondary bundles and occurs between the other two types, and on the inferior portion of the intermediate type.* In maize, according to Combs, the sheath in cross section shows, beginning at the upper surface, the epidermis of large, thin-walled cells, immediately inside of which is stereome in patches, which are located opposite the large bundles on the outer side. Then comes the inner area of the sheath, made up of large, polygonal, colorless, thin-walled parenchyma cells.

The outer or lower surface of the sheath presents an entirly different aspect and varies greatly with the variety of corn. Generally speaking, it is more or less ribbed, caused by the large fibro-vascular bundles. The creases have colorless unicellular hairs which are usually not developed on the epidermis over the bundles. The epidermal cells are small and thick-walled, and protect the plant against drouth and other injuries. Beneath the outer epidermis occur the bundles referred to above, usually with intervening smaller ones, but this varies with different corns. For example, a Mexican corn, number 1, shows two sizes of bundles not connected with each other, forming no external ridges, and the epidermis shows only a few very short spur-like hairs, while a form from South America shows heavy ridges, many hairs, and only one kind of bundle.

In all cases there exists an area of stereome between the bundles and the outer epidermis.

The only chlorophyll in the sheath is located in the chlorophyll parenchyma sheath which surrounds the bundles, except a portion on the outer side which is occupied by stereome.

The anatomy of the species thus far considered here, are

* Proc. Ia. Acad. Sci., 5: 201. Contr. Bot. Dept. Ia. State College of Agr. and Mech. Arts. 10: 6.

such as belong to the types of plants known as halophytic, xerophytic, and mesophytic. Of the fourth type, hydrophytic, the genus *Leersia* is good representative, especially *Leersia oryzoides* which has been well described by Mr. Holm.* In this species the mestome bundles are of three types. A thick-walled mestome sheath, in connection with a layer of thick-walled parenchyma, separate the leptome from the hadrome. Leptome and hadrome are well developed. The largest bundles are not so numerous as the smaller ones of the second degree; in the latter a distinct mestome sheath occurs inside of the colorless parenchyma. The thick-walled parenchyma between leptome and hadrome is absent. The smaller type of bundles contain only leptome with a distinct mestome sheath. Mr. Holm further remarks that in addition to these forms of bundles, which lie in the same plain, there are from one to three very small ones which belong to the upper face of the mid-nerve and this is peculiar to the genus Leersia.

Epidermis.—The epidermal cells are quite irregular, varying greatly in size. For the purpose of this description it will be convenient to take up the epidermal cells under two headings. First, the general character of cell. Secondly, the bulliform. We may obtain an idea of the diversity of the structure by a consideration of some of the different species. One type is very well represented in *Bromus inermis.*†

Here the epidermal cells are large, regular and well-developed, with a thick cuticle. The cuticle is thicker below and above the mestome bundles than elsewhere. Trichomes are absent. Stomata occur on both surfaces of the leaf, but especially between the bulliform cells.

In *Festuca tenella*, according to Mrs. Hansen,‡ the epidermal cells covering the stereome are thick-walled and not as large as the other epidermal cells. In *Andropogon nutans*§ the epidermal cells are very large, and nearly equal in diameter. The cuticle is strongly developed with hair-like projections, more abundant on the lower than on the upper surface.

Mr. C. R. Ball has described the epidermal cells of *Eragrostis pectinacea*, as having thicker-walled cells than in *Eragrostis purshii*‖ the latter being a species adapted to a dry and

* A study of some anatomical characters of North American Gramineæ. IV. Bot. Gazette. 17: 358. *pl. 21.*

† Emma Sirrine, l. c. 122.

‡ Emma Pammel, l. c. 129. *pl. 9. f. 2. pl. 10, f. 5 and 6.*

§ C. B. Weaver, l. c. 133. *pl. 12. f. 1 and 5. pl. 15 f. 14.*

‖ l. c. 141. *pl. 16. f. 2. pl. 18. f. 15-16.*

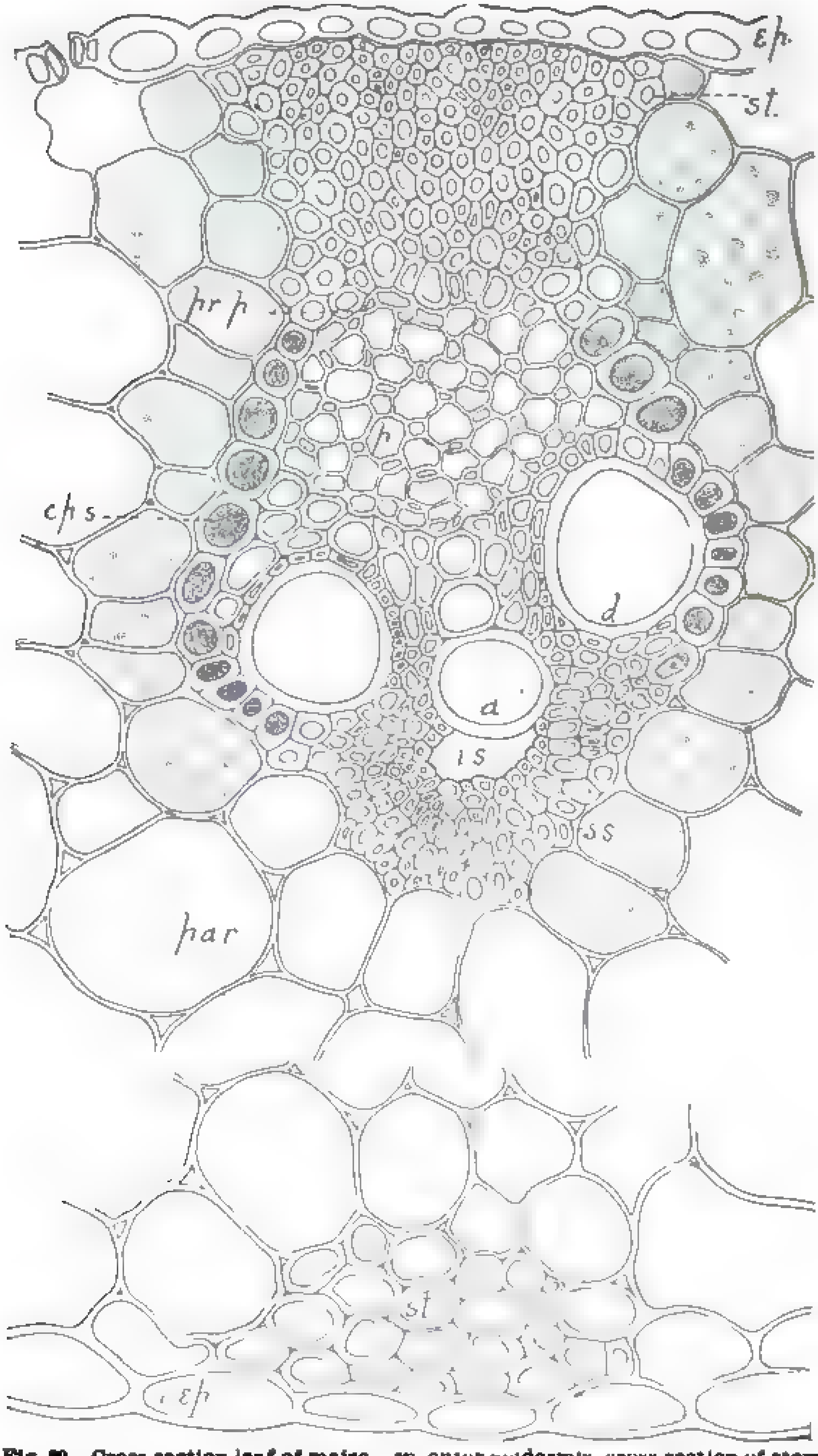


Fig. 29. Cross-section leaf of maize. *ep*, outer epidermis, cross-section of stoma to the left; *p*, soft bast or phloem and companion cells; *cps*, chlorophyll-bearing parenchyma; *d*, duct; *a*, ringed vessel; *is*, intercellular space, *ss*, *st*, stereome; *iep*, inner epidermis. (Combs.)

sandy soil. The cells of *Eragrostis purshii* vary considerably in size, being smaller above or below the bundles than those adjacent to the mesophyll.

In *Sporobolus cryptandrus** the cells have a particularly well developed cuticle. Miss Ogden describes a most peculiar kind of epidermal cells in *Eragrostis obtusiflora* with curved, beak-like expansions that project from the stomata; the cells are very unevenly thickened.

Scent glands.—Another most in'eresting feature to be added to the epidermal layer is the peculiar glands which grow on certain grasses. One of the best known illustrations of glandular trichomes in grasses occurs in the common stink grass (*Eragrostis major*). These glands were first studied by Professor Trelease.†

The somewhat similar glands of *Sporobolus heterolepsis* had previously been studied by C. E. Bessey.‡

Recently Mr. C. R. Ball has studied the glands of *Fragrostis major.* The following is condensed from papers by Mr. Ball and Professor Trelease. The small projections, or scent glands as they are known, are epidermal structures consisting of the single layer of cells. Those at the center are considerably elongated and the parenchyma cells are provided with thick-pitted walls. Those in the center are much thinner-walled. As compared with the unmodified epidermal cells, these elongated glandular cells are also thin-walled at top, where, in common with the other elements of the epidermis, they are invested with a rather heavy cuticle. In some cases this membrane is seen to be free from the crater of the gland in the form of a blister, while in others it has been ruptured, so that only fragments are present. Miss Ogden describes glandular bodies as occurring in *Eragrostis obtusiflora.* In her description it is stated that these glands are provided with a narrow neck and a capitate exodermal portion.

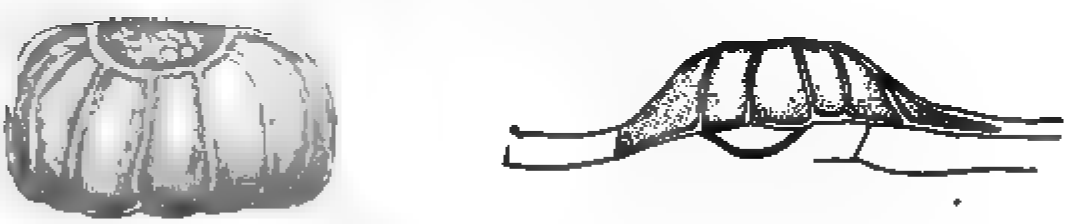


Fig. 36. Scent glands of stink grass (*Eragrostis major*). Figure to right, surface view; left view in section. (Ball.)

*Emma Sirrine and Emma Pammel, l. c. 153.

†The glands of Eragrostis major Host. Proc. Soc. Proc. Agrl. Sci., 10: 79. 1889.

‡Glands on a grass. Am. Nat., 18: 420, *f. 1.* 1884.

Bulliform cells.—Between the nerves occur peculiar epidermal cells which are wedge-shaped; these are known as bulliform cells. Hackel* says these are arranged in the form of a fan whose growth and expansion causes the blades to open out; in those leaves which are rolled in the bud these cells are only found on each side of the mid-rib. Excellent bulliform cells occur in orchard grass, Spartina, etc. In some species of Sporobolus, the leaves are rolled up much of the time. Where the leaves open the bulliform cells are large and penetrate deeply. In *Festuca tenella* and some other species of the genus the leaves do not open and hence bulliform cells are absent, or, but slightly developed. This is also true of Stipa and Nardus. It is owing to this peculiar cell development that the leaves of Sporobolus roll up so easily when they become dry. It requires excessive moisture to open them. Excessive transpiration during dry weather causes the leaf blades to roll up because they have lost their turgescence, but when the atmosphere is moist they flatten out. The bulliform cells afford protection to our wild prairie grasses, and thus they pass the hot, dry winds unharmed while many cultivated grasses are injured. The lower side of the leaf is protected by the strongly developed cuticle which prevents transpiration.

Professor Beal, who has made a study of the bulliform cells of many leaves, says as follows: "The leaves of *Poa* have two bands, one on each side of the middle. *Andropogon squarrosus* has one band on each side of the middle and a small one at each edge. The leaf of the *Phleum pratense* has one band of several shallow cells on each side of the middle and others between the veins. The leaves of *Zea mays* have a band between each two primary bundles and above each third class bundle. The leaves of the *Leersia oryzoides* have numerous bands on the upper surface on each side of the middle, and on each side of the keel on the lower side. The leaf *Amphicarpum purshii* has opposite bands of bulliform cells on both surfaces. Those above are most prominent. In case of the leaves of *Panicum plicatum* the bands of bulliform cells are first on the upper side then on the lower, and are found in grooves. The leaves of *Andropogon prinoides* have large epidermal cells of nearly uniform size, distributed along the surface, excepting over the veins."

*True grasses, English translation, Lamson, Scribner, and Southworth. 9.

From studies made in the botanical laboratory of the Iowa Agricultural College, the bulliform cells of different species of grass are sufficiently diagnostic in grasses occurring under different climatic and soil conditions, to warrant a study of them. These differences may best be considered by taking some of the different species. Mr. Ball* found that the bulliform cells of Eragrostis are two or three in number, and in some cases not easily distinguishable from the epidermal cells.

Mr. Theo. Holm† says of *Leersia oryzoides:* "The bulliform cells form grooves between all of the mestome bundles and are of unequal lengths, the middle cells being the largest, with a narrowing towards the surface, thus being nearly triangular in cross sections, the cells on the sides gradually becoming smaller." Both of these species are adapted to hydrophytic conditions and hence the bulliform cells need not be nearly so well developed as in species adapted to dry weather conditions. This is also true to some extent of *Panicum proliferum*, in which the bulliform cells vary from two to five, usually consisting of one large or two large central cells. In *Sporobolus cryptandrus* and *S. heterolepis* the bulliform cells are very nicely developed. According to Miss Emma Sirrine and Mrs. Hansen,‡ the bulliform cells of *S. hetrolepis* occur in four or five rows, a large central cell and three or four smaller cells on each side. In *S. cryptandrus* they are somewhat larger than those in *S. heterolepis.* In the latter there are usually two or three quite large cells and two smaller on each side. One or two groups of bulliform cells occur between a large mestome bundle, and, as in *S. heterolepis*, these do not occur between the last two bundles. In *Andropogon scoparius* the bulliform cells occur as a continuous row, excepting over the secondary bundles. In Johnson grass the bulliform cells gradually merge into the epidermal cells. The bulliform cells of sugar cane§, which is adapted to the hydrophytic conditions, consist of three or sometimes more rows quite strongly marked. In fact these cells are very much larger than the remaining epidermal cells.

It may be interesting here to briefly give the structure of the bulliform cells of the various varieties of corn. These have been studied by Mr. Combs.

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*l. c.

†*IV* Bot. Gazette, 17: 359.

‡l. c. 151.

§Wm. C. Stubbs. Sugar Cane, *1.* 20. *f.* 6. 8.

The bulliform areas are composed of from three to seven rows of polygonal cells with thin walls. They are arranged longitudinally with the leaf and are occasionally interrupted by or grade into the exserted cells about the base of the large hairs. These areas usually consist of about fourteen rows of epidermal cells. They are located alternately with the veins. The epidermis of the lower or outer face is much the same as above, except that the bulliform cells, hairs, and spur-like hairs or tubercles are wanting, and the walls are thicker.

Stomata.—The stomata occur in longitudinal rows; the two narrow guardian cells containing chlorophyll are surrounded by two large secondary cells. A thin cross-section of leaf of *Sporobolus heterolepis* shows a nearly continuous row of rectangular epidermal cells, broken only by the stomata.

The ecological parts of the grass leaf are rather instructive. The cuticle and cell walls are strongly developed in the corn. The same is true of many other dry climate grasses. In grasses like barnyard grass, the epidermal cells are larger and the cell walls and cuticle less developed, as they grow in places where moisture is obtained easier and transpiration is not so excessive. The chlorophyll-bearing parenchyma surrounds the bundles and differs somewhat in different genera. In *Sporobolus heterolepis* large parenchyma cells surround the bundles. These are joined by one or more rows of smaller cells to the outside. In this arrangement there is economy, since the plant can carry away the elaborated food materials. The blades as well as sheath are frequently provided with trichomes, abundantly produced in *Bromus mollis, Leersia oryzoides,* Zea (Mexican corn). Those interested in a further study of the anatomy of leaves should consult specially the works of Hackel, Holm, Miss Emma Sirrine, Miss Emma Pammel, Duval Jouve, Ball, Combs and others. These studies are of value from a systematic standpoint, as has been abundantly shown by Holm, Jouve, Ball and others. The character of bundles, sclerenchyma, bulliform cells vary in different genera and species, and often may be used to determine the species and help to separate them, but we should not lose sight of the fact that allied species present somewhat similar characters and usually have a similar structure.

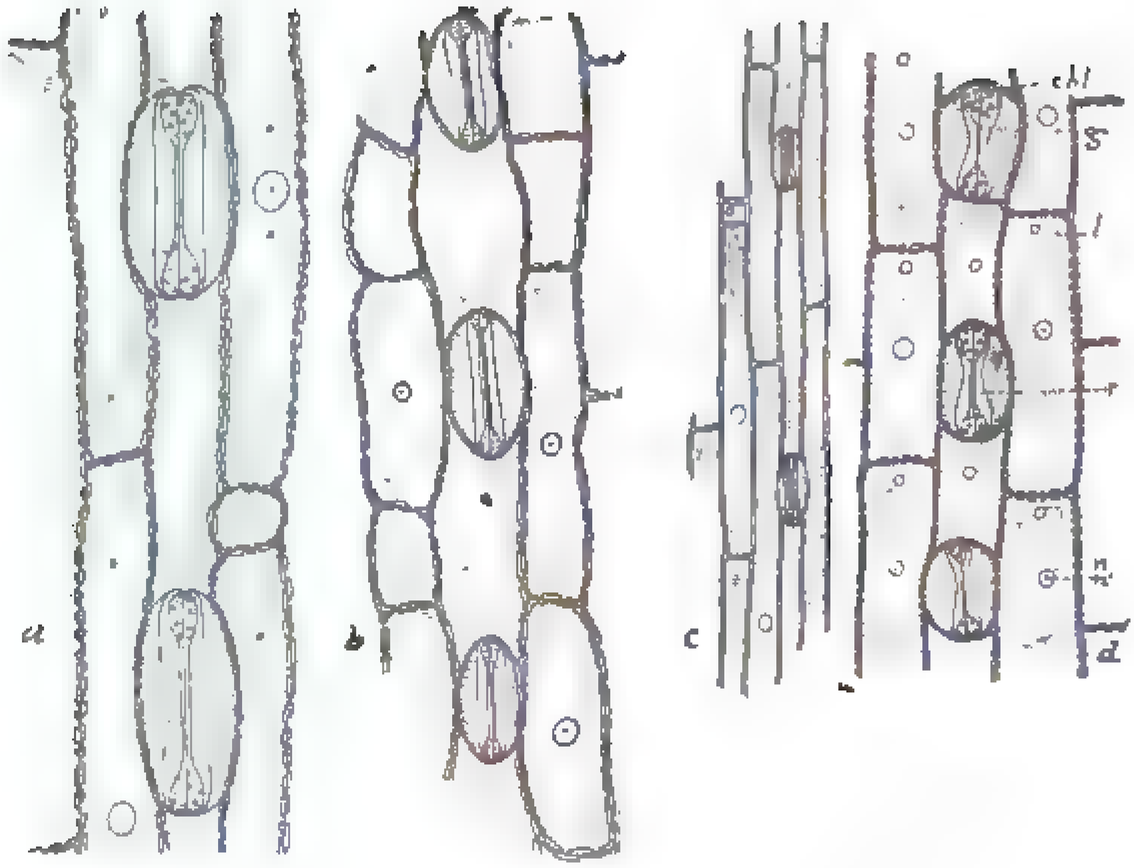

Fig. [illegible] Stomata of grasses. *a*, wheat; *b*, *Panicum crus-galli*; *c*, *Bromus inermis*; *d*, *Poa pratensis*; *chl*, chlorophyll grains, *g*, guardian cells; *l*, leucoplastids; *r*, rift; *n*, nucleus; *n'*, nucleolus. (King.)

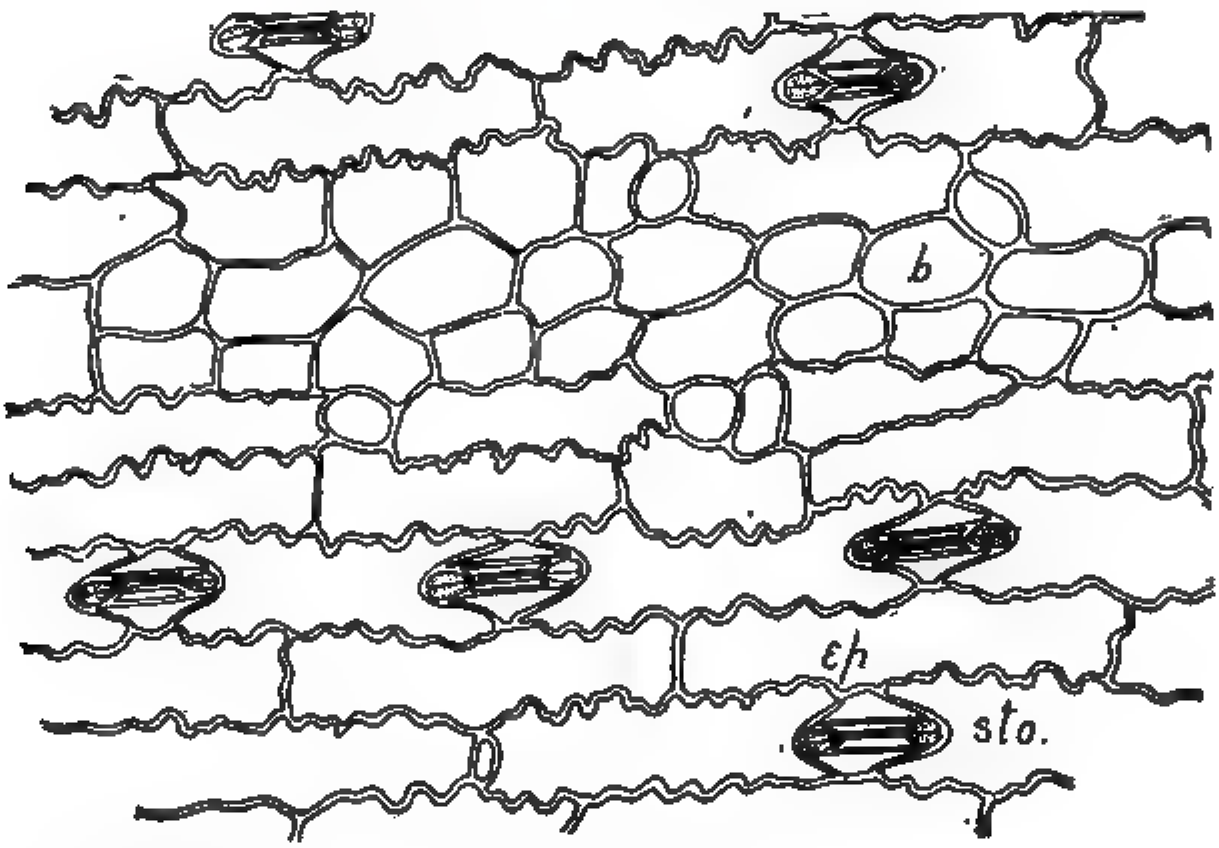

Fig. [illegible] Stomata of maize leaf. *b*, bulliform cells, upper surface; *ep*, epidermal cells with irregular walls; *sto*, stoma. (Combs.)

The Flower.

Parts of the flower.—The flowers of grasses possess only the essential organs—the stamens and pistils. The bracts enclosing these are modified leaves or leaf sheaths and prophylla. Sometimes the stamens and pistils are separated, when the flowers are either male or staminate (containing stamens only), or female or pistillate (containing pistils only). These staminate and pistillate flowers may occupy different parts of the same plant or (more rarely) entirely distinct plants. Flowers having both stamens and pistils are termed hermaphrodite.

In each flower there are usually three stamens. These have slender filaments, and usually versatile, sometimes basifixed, two-celled anthers, which are pale yellow, sometimes nearly white, or purple, or some shade of red. The pistil consists of the ovary and usually two feathery or plumose stigmas, which may be sessile or raised on short or long and more or less divided styles.

The fruit or ripened ovary constitutes the "grain." This is a true caryopis, *i. e.*, a dry one-seeded fruit in which the outer covering or pericarp is closely adherent to the seed. The "grass seed" of commerce consists of the grain enveloped usually in more or less "chaff" (glumes and paleas).

Arrangement of the flowers.—The arrangement of the flowers in grasses is peculiar. They are situated in what are termed spikelets, either solitary (one flowered spikelets) or two or more together (two to several or many-flowered spikelets). Each flower is located in the axil of a chaff-like bract or glume called the flowering glume (really a leaf-sheath). At the base of the spikelet there are usually two bracts or glumes having no flowers in their axils; these are the outer or empty glumes.

Hackel, in his work on grasses, says: "The palea, which, with its enclosed flower, stands opposite the flowering glume, does not belong to the main axis of the spikelet, but to the branch which bears the flower. That this relation of parts may be gradually obliterated in the one-flowered grasses, and that the palea may be moved back upon the main axis, has been explained above. As long as an axis or a rudiment of one, at least in its earlier stage, is visible beyond the palea, this latter possesses (like the prophylla of the culm branches) two keels, or at least two lateral nerves, without a mid-rib;

Fig. 33. Inflorescence of *Koeleria cristata* Pers. *Eatonia obtusata* Gray. *Eatonia pennsylvanica* Gray.

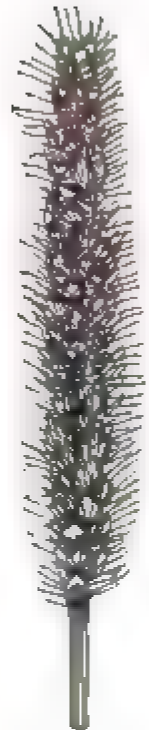

Fig. 34. Spike of *Setaria glauca*. (King.)

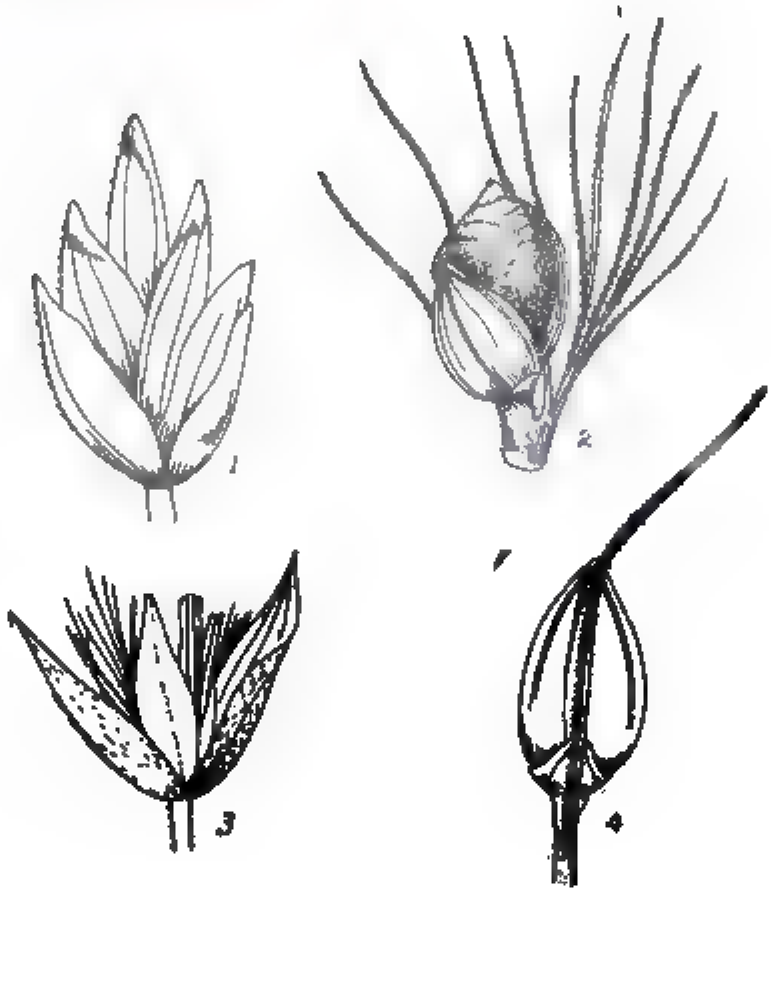

Fig. 35. Spikelets of grasses. 1, *Poa pratensis*, spikelet four-flowered, the two lower scales the sterile glumes; the flowering glume of others only show; 2, *Setaria glauca*; 3, Spikelet of *Calamagrostis canadensis*, the two sterile glumes, flowering glumes and palet; 4, *Setaria verticillata*.

Fig. 37. Pollination of Maize. A, young ear with stigmas; B, to the right, pistillate flower with scales and chaff; B, above staminate flower; J, pistil; J, G, ovule. (Details after Nees, Hackel.)

only when all trace of the axis is absent does the palea become from one to many nerved (with a mid-rib) or nerveless. It is almost always of a more delicate texture than the flowering glume, its edges are usually turned in, and it has a furrow instead of a mid-rib. The prophyllum of the culm branches

has no blade, and the palea resembles it in being almost always (excepting Amphipogon) awnless; and as the former is sometimes split in two parts (Cynodon), so the palea is often split at the time the fruit is mature (many Sporoboli and Triticum monococcum L.). This state has been understood by some authors as originally bifoliate, and false genera have been established upon it by some (Diachyrium Griseb, etc.). The palea is completely aborted in many Andropogoneæ and species of Agrostis."

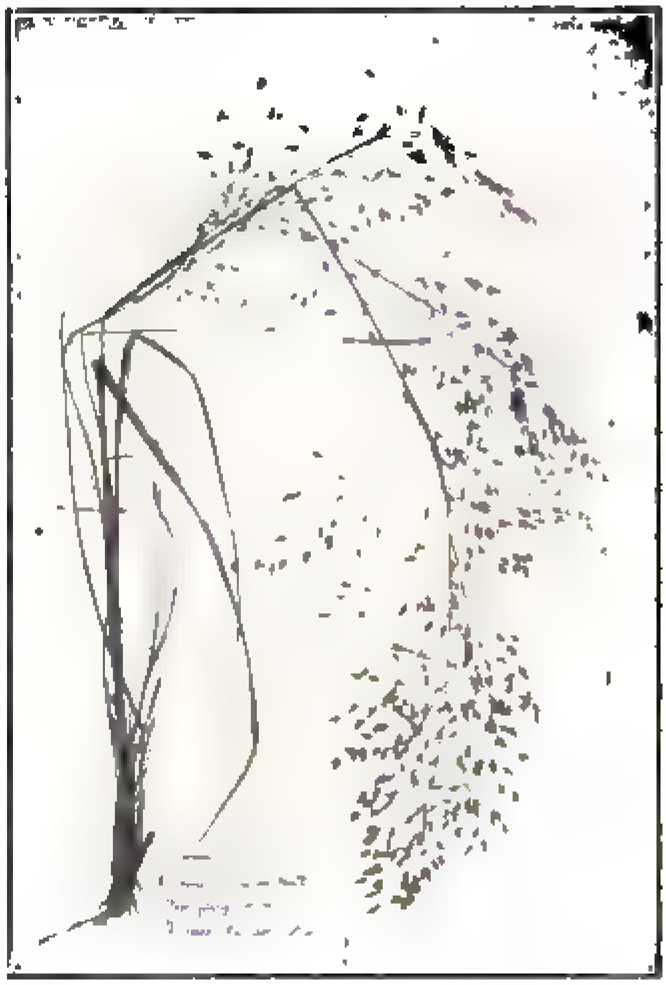

Fig 38 *Eragrostis trichodes*. Loose paniculate inflorescence.

The axis to which these glumes are attached is termed the rachilla, and between each flower and this rachilla there is usually a two-nerved bract, the palea the prophyllum to the floral branch. In one-flowered spikelets where there is no extension or prolongation of the rachilla, this palea is apparently opposite the flowering glume. The lower pair of glumes—the empty ones—often differ from each other in size or length, and sometimes, though rarely, one or both are absent. In others they occur as rudiments, as in Leersia. In a few cases it consists of but a few scales,

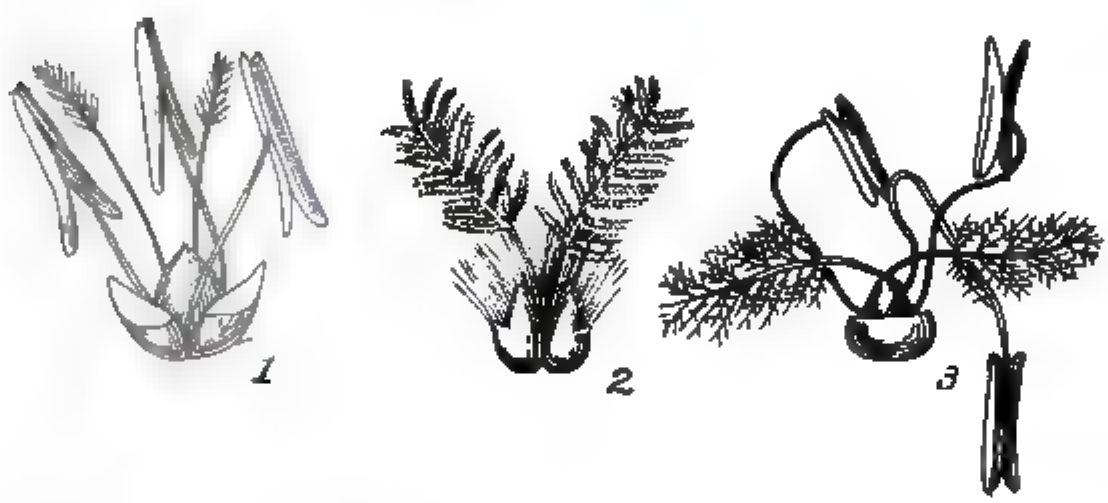

Fig. 39. Showing lodicules below stamens 1, *Panicum miliaceum*; 2, *Avena sativa*; 3, *Melica nutans*. (After Nees, Hackel.)

generally two, rarely more than two. In this case they are generally described as sterile flowers as in such genera, Panicum and Andropogon. This question is discussed more at length by Hackel and Scribner.*

The glumes may be awned or "bearded," or awnless; they may be sharp-pointed, obtuse or toothed at the apex; they may be nerveless or one to many-nerved. As to

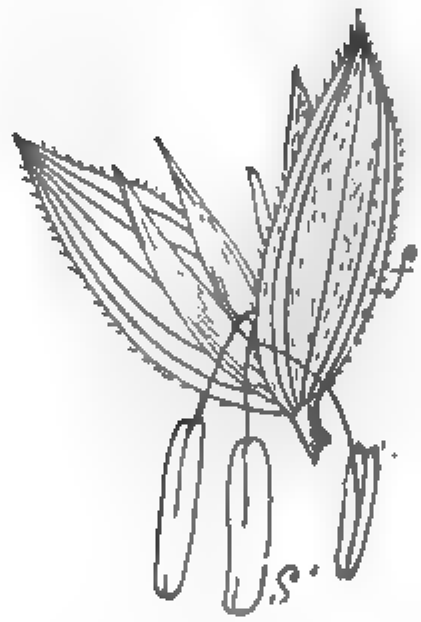

Fig. 39 B. *Zea mays* a single spikelet with staemens.

other variations it is necessary to refer the reader to the larger descriptive works on botany.

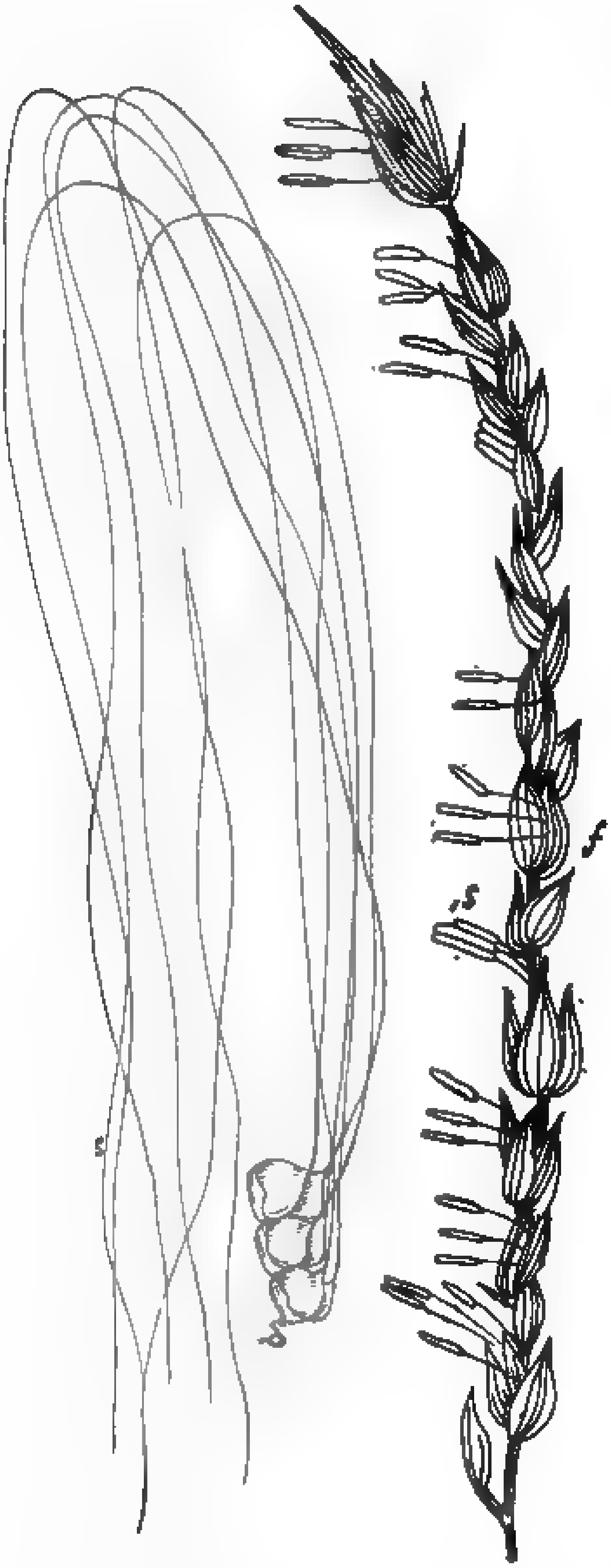

Fig. 39 A. *Zea mays*. To the left, pistil; g, ovary; s, stigma; to the right, f, flowers; s, staemens.

Opposite the pales and above the flowering glume occurs two small delicate scales known as the lodicules. Sometimes there are more than two, sometimes they are wanting. These lodicules stand close together. In the front they are

*English translation True Grasses, from Die Natuerlichen Pflanzenfamilien. See also Bentham, Notes on Gramineae. Linnean Soc. Jour. Bot., 19: 32.

close together. Various views have been held in regard to these lodicules. The question has been discussed by Bentham, who states: "It might therefore be suggested that the palea and lodicules of Gramineæ represent perianth-segments of an outer and inner series, although I by no means pretend to assert it as a proved fact." Hackel* in an early paper discussed the original homology of these organs. In his own words in a later paper, "The author has endeavored to prove that the anterior scales represent the halves of a leaf which sometimes (Melica, Fig. 81, f.) remains undivided, and can be regarded as a second, and the posterior scale as a third, palea. The anomalous condition of these paleas (in respect to the ordinary palea) is explained by their biological properties. The rapid swelling of the bases at least, causes the separation of the flowering glume and palea, and consequently the opening of the flower. In grasses where they swell only a little the spikelets open but slightly, and where the lodicules are membranous or entirely lacking, the spikelet remains entirely closed at the sides, and the reproductive organ protrudes only at the apex (compare Anthoxanthum, Alopecurus, etc.). The absence of the lodicules is not necessarily a case of abortion; for if they are bractlets, a decrease in their number (as in the Juncaceæ) is not very remarkable. Their large number (eight or more) and apparent spiral arrangement is striking in Ochlandra; here their relations have, however, still to be studied in living material."

The subject of lodicules again finds discussion in a recent paper by W. W. Rowlee.†

Arrangement of the flowers.—The arrangement of the spikelets upon the stem constitutes what is termed the inflorescence, or what we often hear erroneously called the "head." If that portion of the main axis or stem which bears the spikelets is unbranched so that these are sessile (*i. e.*, without pedicels), the inflorescence is a spike, as in wheat or rye grass; when the main axis is branched, each branch forming a pedicel to a single spikelet, the inflorescence is a raceme. This form is not common. Usually the primary branches branch again and again, resulting in the formation of a panicle. The panicle may be open or widely spreading, as in oats or in Kentucky blue-grass; or, if the branches are very short, it may be narrow

* Engler's bot. Jahrbuecher. 1: 33.

† The morphological significance of grasses. Bot. Gaz 25: 199.

and spike-like, as in timothy or in meadow foxtail. All gradations of form between these two extremes occur.

Pollination and fertilization.—Grasses are mostly anaemophilous, that is, pollinated by the wind. Flowers, as stated above, are mostly hermaphrodite; some are mon ecious and a few dioecious. In monoecious grasses like Zea the staminate flowers form the so-called tassel. Each staminate flower contains three stamens; when mature they hang loosely from the flower. The pollen consists of small round grains easily shaken out of the versatile anthers. The slightest breeze suffices to set the anthers in motion, causing them to shed "loads of pollen." Since the pollen is light it may be easily carried by the wind. The pistillate flowers occur in the axils of the leaves and constitute the so-called cob. Each ovule has coming from it a long, slender filiform thread, the stigma, provided with plumose hairs. These plumose hairs are readily made out with the naked eye and are for the purpose of holding the pollen grains. The moist surface of the stigma causes the pollen grain to germinate. It sends a slender tube down the style to the ovule where the generative nucleus unites with the egg cell of the ovule, and as a result of this fertilization the kernel develops into a seed. Corn produces an enormous amount of pollen. Much of this is of course wasted. The staminate flowers are visited by honey bees and other insects chiefly for the pollen. Corn, when in flower, has a decided odor.

Bulbilis dactyloides is said to be dioecious. Mr. Plank* made some observations which led him to believe that the grass was not dioecious but monoecious, and Professor Hitchcock,† in order to verify this statement, conducted the following experiments. A few seeds of the species were germinated. A single stolon was transferred to an out-door plat. This produced numerous stolons, gradually spreading over the ground. The second season witnessed no flowers, but the third season both staminate and pistillate flowers were produced, the staminate preponderating. The flowers made their appearance mostly at the nodes, so that in reality they started as independent plants.

In *Distichlis spicata* and occasionally *Poa arachnifera* the plants are dioecious. In these cases the pollen must come from other plants.

**Buchloe dactyloides* Englm. not a dioecious grass. Bul. Torr. 19: 303. 1892.
†Note on buffalo grass. Bot. Gazette. 20: 464.

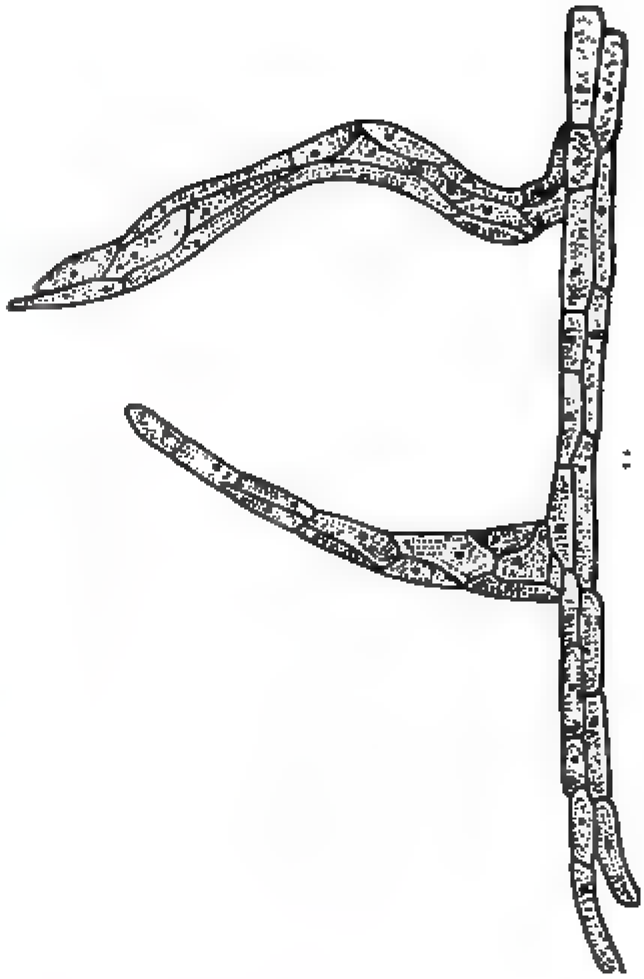

Fig. 40. Plumose stigmas of maize. (Pammel and King.)

Fig. 42. Pistillate flower, ovules developing. st, styles. (King.)

Fig. 41. Pollen grains of maize mounted in water. (Pammel and King.)

Arrhenatherum avenaceum has hermaphrodite flowers as well as staminate. The anthers are long and pendulous. The least jar or the slightest breeze will cause a shower of pollen to issue from the anthers; the very plumose stigmas are exposed and

readily receive the pollen. Self-pollination can occur in many grasses as stamens and pistils mature at the same time, but this is prevented in tall meadow oat grass and others by the difference in time in which stamens and pistils mature. In this grass the pistil matures first and is therefore proterogynous. When the pollen is mature and is shed, the stigmas have wilted and are no longer in a receptive cnditi on. In most grasses stamens mature first and the flowers are proterandous.

The flowers of our *Andropogon provincialis* with digitate spikes are gently blown by the wind. When they come in contact with a neighboring plant they are sure to leave some of the pollen on the receptive stigma. The long, purple plumose stigma is proterogynous, and therefore not ready to receive the pollen when the stamens dehisce. The flowers open during the early morning (5 A. M.), when there is considerable dew on the ground.

Professor Hitchcock* has described quite interestingly the

Fig. 43. The opening of grass-flowers. Beginning to the left: Tall Meadow Oat grass, *Arrhenatherum avenaceum*; Meadow Fox-tail, *Alopecurus pratensis*; Hungarian Brome, *Bromus inermis*; Rye, *Secale cereale*; Meadow Fescue, *Festuca pratensis*.

*Report on a collection of plants made by C. H. Thompson in southwestern Kansas in 1893. Contr. U. S. Nat. Herb., 3: 537.

manner in which grama grass, *Bouteloua oligostachya* is pollinated.

The plants grow closely intermingled, forming a dense, soft mat a few inches in height. The flowers are arranged in one-sided spikes, of which there are usually two or three. The two stigmas protrude from the base of the partially opened glumes and recurve towards the main rachis. The anthers, as is usual in grasses, hang on slender filaments, easily shaken by the slightest breeze. The spikes are so arranged that when acted upon by the wind they turn like vanes. This brings all the spikes in a direction nearly parallel to the wind, the stigmas being to the windward and the anthers to the leeward; thus the stigmas necessarily receive pollen from a different plant. The same adaptation is seen in other species of Bouteloua and in some other grasses.

Many of the flowers of grasses have a pair of small scales, physiologically of great importance, as they assist in the pollination of grasses. The bases of these lodicules are grown together. The rapid swelling of the bases at least causes the separation of the flowering glume and palet, and hence the opening of the flower. These turgid scales may be seen at the time of flowering in many grasses. They are very evident in *Poa arachnifera*, *Panicum miliaceum*, *Avena sativa*, *Bromus mollis* and *Festuca elatior*. In grasses where these scales swell but little, the flowers do not open very far. Where they are absent the spikelets are closed at the sides and the stamens and pistil only protrude at the apex. The time of opening of grasses in different genera varies greatly. It is well known that temperature and moisture greatly influence the opening of flowers. Rain and low temperature may retard the opening, not only hours but days. Dry air and a high temperature also retard opening. The flowers of grasses open, as a rule, early in the morning, usually when there is some dew. *Festuca pratensis* opens before 7 A. M. Mr. F. A. Sirrine found that about Ames the flowers of grasses usually open between 5 and 9 A. M. Some, however, open between 5 and 7 P. M. Kerner von Marilaun* states 4 to 5 A. M. for Poa and Koeleria; 5 to 6 A. M. for *Brazia media*, *Aira cæspitosa*, wheat and barley. Rye, 9 A. M. This is, however, not always the case in cereals, as they may open at any time of the day.

* Pflanzenleben. 2: 139.

Hays and Boss* state that the flowers of wheat open at 40 minutes past 4 and closed at 18 minutes past 5 A. M., in Minnesota. Flowers of oats and timothy open between 7 an A. M.

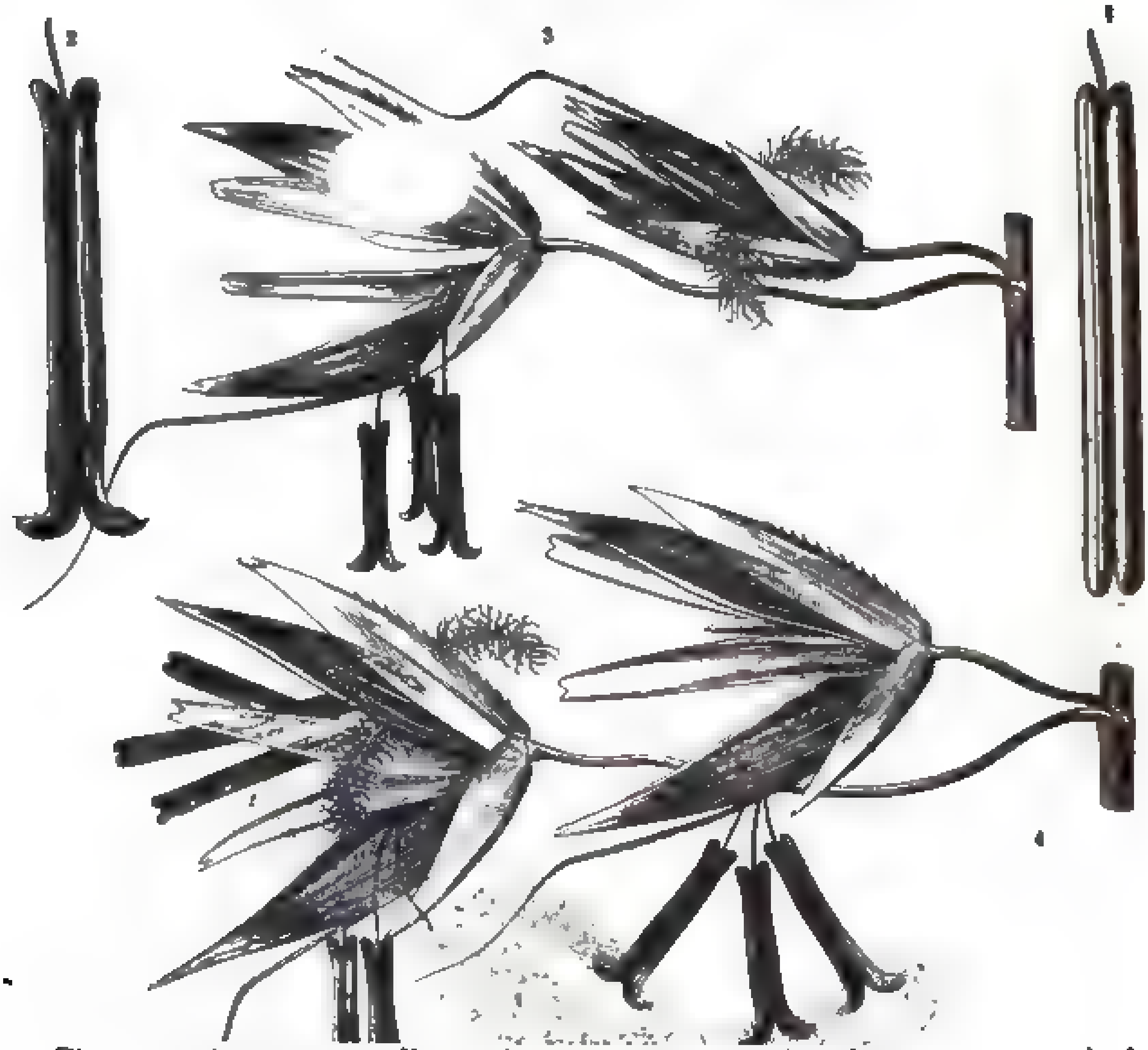

Fig. 44. Pollination of tall meadow oat grass (*Arrhenatherum avenaceum.*) 1, Stamens before pollen is discharged; 2, Pollen discharged from anther; 3, Pollen discharged; 4, Pollen in the act of discharging. (After Kerner von Marilaun.)

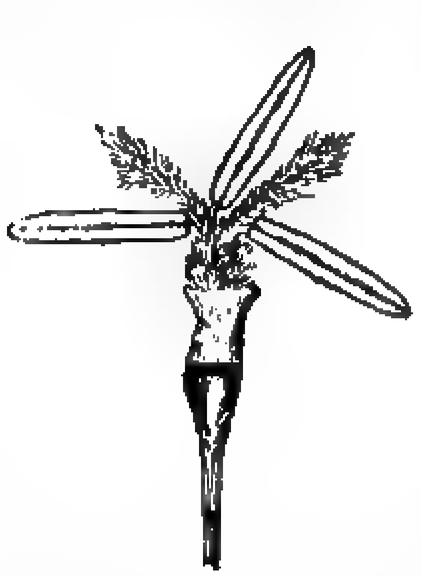

Fig. 44 B. Flower of wheat with stamens and pistil. (After Sanders.)

Agrostis, 11 A. M.; Elymus, between 12 and 1 P. M. Agropyron at 4; Holcus opens its flowers twice during the day, at 8 A. M. and at 7 P. M., provided atmospheric conditions are favorable; when the temperature is not below 57° Fahrenheit.

Beal says, in regard to the length of time a grass remains in flower: "As a rule, a certain specified flower of a grass remains open only for a short time, but different flowers of a plant may appear at successive periods extending over eight days,

*Wheat varieties, breeding, cultivation. Bull. Univ. of Minn. Agrl. Exp. Sta. 62: 415.

more or less, in Indian corn; seven days, more or less, in timothy, several days in oats and wheat, and for a much longer period in branching grasses like Eragostis and Muhlenbergia." Several grasses produce what are known as cleistogamous flowers. *Amphicarpum purshii*, indigenous to New Jersey and southward, produces two kinds of flowers. Those with open flowers sterile, while those borne on the small runners at the base of the culms are abundantly fertile. *Leersia oryzoides* produces cleitsogamous flowers.

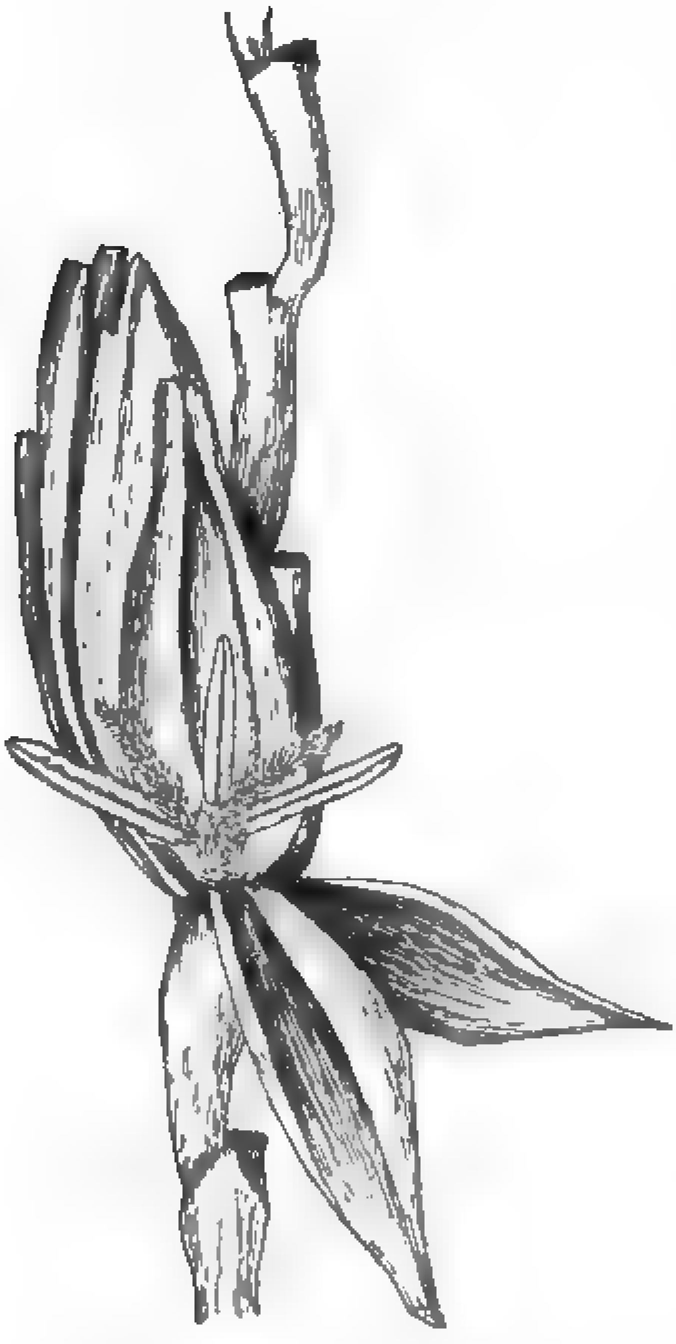

Fig. 44 A. Spikelet of wheat showing glumes, palet, stamens and pistil. (After Saunders.)

Cross-fertilization.—Hackel has shown that cross-fertilization is much more rare and difficult in barley, and in certain races like the six-ranked, the short spiked two-ranked and the peacock barley, the flower of the grasses, especially in some climates, never open and consequently cross-fertilization is impossible. Wheat is also pollinated in the bud during cloudy and rainy weather. In rye, on the other hand, the rule is to have the flowers cross-pollinated. They have in fact lost the power of self pollination. Cross-fertilization takes place readily in nature as shown in numerous forms of corn, such as sweet, pop, dent and flint. Corn is remarkable in showing the immediate effect of cross-fertilization or xenia the first season, though it is also evident* in succeeding generations.

*Just as I am reading proof there has come to hand a valuable paper on Xenia, by Webber. Bull. U. S. Dept. of Agr. Div. of Veg. Path. and Veg. Phys. 22: 1900.

In wheat, according to Hays and Boss,* unusual variation may occur. They state that the fife and blue stem parents only had very short awns, while in the progeny there are several types with awns of various lengths. Several of the plants had dark-brown chaff, others chaff with a light metallic tinge. Some of these varieties may be due to previous crosses, and the tendency of the plants to vary. The two varieties crossed are not closely related, one parent having hairy chaff and the other smooth.

Fig. 45. Flowers of *Glyceria fluitans*, stamens and pistils. (King.)

Hybrids.

Hybrids have been produced in grasses but they are rather difficult to work with, owing to the delicacy of the flower. The remarkable wheat and rye hybrids of Bliss Carman in which fertile offspring took place in two distinct genera, Triticum and Secale, are worthy of notice.

Focke† in his work on plant bybrids notes a number of hybrid grasses. Thus he records a hybrid between the *Avena sativa* and *A. orientalis*. There are also several hybrids between species of the genera Poa and Calamagrostis and Alopecurus and Bromus. He also records a hybrid between Aegilops and Triticum. According to this it is stated that after several years of culture a variety with constant characters is produced which was called Aegilops blé by Fabre. It seems extremely doubtful whether Fabre had a genuine hybrid in this instance.

Wilson‡ seems to have produced a fertile hybrid between Triticum and Secale, and they have even reported bigeneric bybrids between Agropyron and Elymus.

Immediate and secondary influence.—It is well known that in some cases pollen has an immediate influence on the fruit or seed. This has long been known to be the case in corn. As long ago as 1758§ it was observed that when differently colored varieties grew near each other they affected each other's seed. Later experiments were made by Dr. Savi and Professor Hil-

* Wheat: varieties, breeding, cultivation. Bull. Minn. Agr. Exp. Sta. 62: 400. This valuable bulletin gives a great deal of valuable information on the subject.

† Die Pflanzen mischlinge ein Beitrag zur Biologie der Gewächse. 407.

‡ Trans. Bot. Soc. Edinb. 12: 286.

§ Darwin: Animals and plants under domestication. 1: 430.

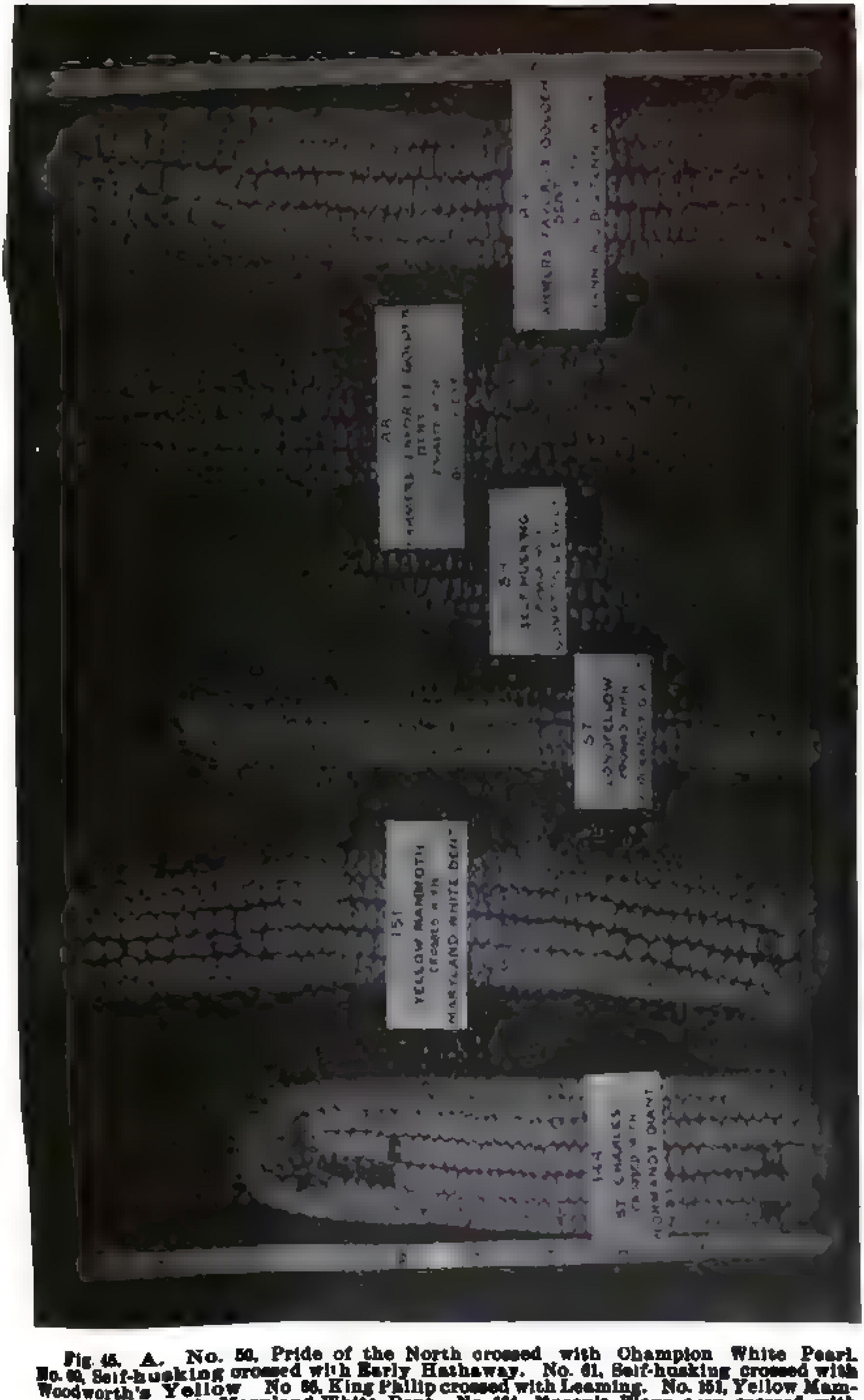

Fig. 45. A. No. 50, Pride of the North crossed with Champion White Pearl. No. 60, Self-husking crossed with Early Hathaway. No. 61, Self-husking crossed with Woodworth's Yellow No 56, King Philip crossed with Leaming. No. 151, Yellow Mammoth crossed with Maryland White Dent. No. 164, Mason's Flour corn crossed with Conscience. After Kellerman Swingle.

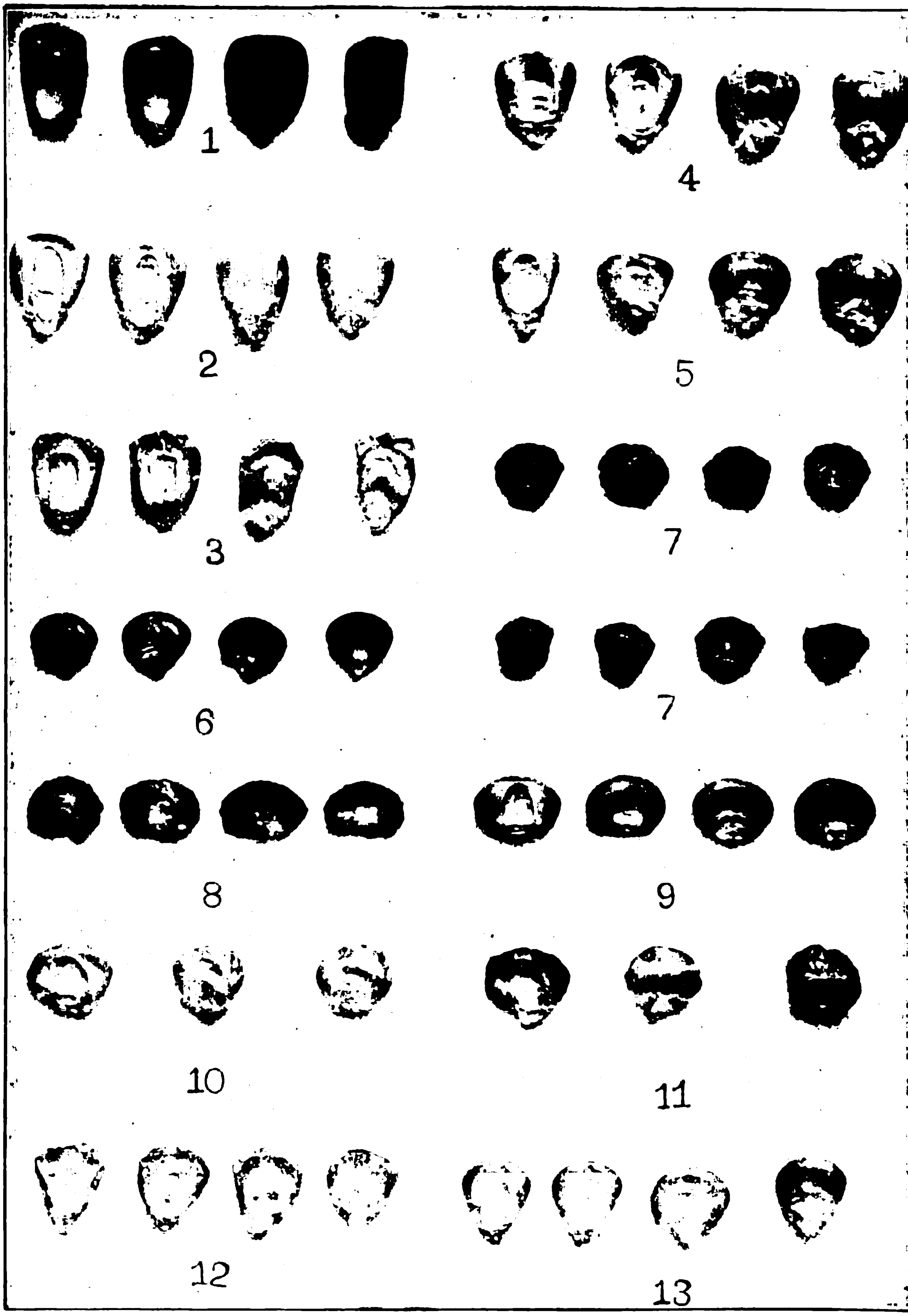

Fig. 45 A. Changes in form and color of kernels of corn produced by xenia. **1. Leaming Yellow,** anterior and posterior views of kernels. 2. Champion White Pearl; two views. 3 Stowell's Evergreen, two views. 4. Stowell's Evergreen, showing xenia from crossing with pollen of Champion White Pearl. 5. Stowell,s Evergreen, showing xenia from crossing with pollen of Leaming Yellow. 6. Gilman Flint, showing xenia from crossing with pollen of Stowell's Evergreen. 8. Black Mexican. 9. Black Mexican, showing xenia from crossing with pollen of Gilman Flint. 10 Stowell's Evergreen, female, X Black Mexican male; kernels are white and transparent resembling the mother parent. 11. Stowell's Evergreen female, X Black Mexican male, showing xenia in blue-black color imparted to the aleurone layer of the endosperm. 12-13. Kernels from an ear of a pure race of white sweet corn, some of which show xenia from crossing with pollen of a yellow Dent race. Those of figure 12 are normal, evidently having been self-fertilized, while those shown in figure 13 show xenia. After Webber, U. S. Dept. of Agr.

Fig 45 B 1-2 First generation Hybrids of Hickory King corn, female, x Cuzco corn, male, and types of parent stalks for comparison.

1 Hybrids of Hickory King female x Cuzco 759 male, (first generation hybrid) showing increased vigor In order to show the size as compared with the parents, the attendant held a stalk of Hickory King in his left hand and one of Cuzco in his right hand

2 Central stalk a hybrid of Hickory King female x Cuzco 759 male, stalk on left, Hickory King, the mother parent, stalk on right Cuzco, the father parent. (Stalks in each case of maximum size). After Webber, U S. Dept. of Agrl.

Fig. 45 C. Comparison of hybrid of Gilman Flint corn female x Hickory King corn male with parents, and ears showing change caused by xenia in composition of kernels

1. Hybrid and parents Hill in center, a first generation hybrid of Gilman Flint female x Hickory King male, grown from one kernel; hill on right, Gilman Flint, the mother parent; hill on left, Hickory King, the father parent.

2. Ear of sweet corn, the smooth kernels of which show xenia from crossing with the pollen of a yellow Dent race. Natural size.

3. Ears of Gilman Flint, the wrinkled kernels of which show xenia from crossing with Stowell's Evergreen. Natural size. After Webber, U. S. Dept. of Agri.

Fig 43F. Method of selecting stock. Two types of plants. The plant at the right has culms, very uneven in length, therefore undesirable, while that at the left has no very tall culms, but many of nearly the same height (After Hays, Minn. Agri. Exp. Sta.)

Fig. 65G. In the upper row the right hand spike is the Blue Stem parent, the left hand one the Fife parent, and the central spike is the average spike of the plant of the first generation The spikes in the middle and lower rows are forms which appear in the one hundred plants of the second generation, all of which came from seeds from the single plant of the previous year. (After Hays, Minn. Agr. Exp. Sta.)

debrand. Both have come to the same conclusion. P. Dudley* writes as follows: "Indian corn is of several colors, as blue, white, red and yellow. If these sorts are planted by themselves, so that no other be near them, they will produce their own color; but if you plant the blue corn in one row of hills, as we term them, and the white or yellow in the next row, they will mix and interchange color." Dr. Sturtevant† says: "Corn, the maize plant, shows in its kernels the influence of cross-fertilization of the same year. Some varieties seem to possess the power of resisting either cross-fertilization or the changes induced thereby." Professor Crozier‡ writes (Cross between Stowell's Evergreen and Yellow Hathaway): "These observations show that foreign pollen affects the appearance of the crossed kernels the first season, but also that an unusual appearance may be due to a cross of the previous year." Professor Beal§ says: "During the past year I planted near each other three hills of the following kinds of corn, well mixed together, viz: Waukashum, White Flint, Black Pop Corn, Early Minnesota Sweet, King Philip and Black Sugar. Every ear showed a mixture produced by pollen from one or more of the varieties except those of the King Philip variety." But Flint corn did not show the effect of pollen from Dent corn in the first year. Kellerman and Swingle,‖ who crossed a large number of varieties, have come to the same conclusions that other observers have, namely: that the so-called varieties of maize cross more or less freely, and the effects may or may not be visible the first year. As a result of some work done on the college grounds Professors Crozier and Rolfs¶ write concerning the immediate influence of cross-fertilization upon the fruit: "In all cases some, and in some cases all of the ears changed in appearance in the direction of the variety furnishing the pollen." A practical gardener, Mr. F. S. White,[1] writes as follows: "The past season I had sixteen varieties of white sweet corn and also a small lot of Black Mexican. When I came to save my seed corn I found grains of this black corn stuck in every variety."

*Philosophical Transactions Abridgment, vol. 6[2]: 204-205. Kellerman and Swingle. Annual Rep. Kansas Agrl. Exp. Sta. 2: 346, 1889.

†Ann. Rep. New York Agrl. Exp. Sta. 2: 37-56.

‡Proc. Soc. Prom. Agrl. Sci. 1887: 1.

§Rep. State Board of Agrl. Mich. 1878: 450.

‖Ann. Rep. Kan. Agrl. Coll. Exp. Sta. 2: 288, 1889.

¶Agrl. Sci., 4: 23.

[1]Iowa State Register, Dec. 11. 1891.

Walter T. Swingle and Herbert J. Webber, in a paper on Hybrids and their utilization in Plant Breeding, say as follows*:

The most convincing series of experiments was carried out by the famous French plant breeder, Henry L. de Vilmorin, in 1866. In the spring of that year he planted a dozen varieties of maize from 1,000 to 1,300 feet apart, which distance was found sufficient to prevent spontaneous inter-crossing by wind-blown pollen. The ears to be crossed were enveloped in thin flannel, which excluded pollen perfectly, for such ears, if not artificially pollinated, never gave a single kernel. To have a standard for comparison, an inclosed ear of each sort was artificially pollinated from the same sort. The ears thus obtained were imperfectly filled, but the kernels reproduced all the characters of the seed planted. On the other hand, when inclosed ears were artificially crossed 'with pollen from another sort, * * * the ears often, but not always, contained kernels showing the characteristics of their male parent. The proportion of such grains, when they existed, was very inconstant, being liable to vary from 1 to 60 per cent.' The effect was limited to changes in the color of the kernels. In most cases the pollen of a black corn was used in crossing, and this color exists in the substance of the kernel. No conclusions were drawn except from plats of maize, the ears of which, when left exposed or fertilized with their own pollen, reproduced without change the sort planted.

"In 1867 Hildebrand reported an experiment in crossing corn, using a yellow sort for the female and a dark brown sort for the male. Realizing that the older experiments had been faulty, since no proof was given that the sort used as the female parent was pure and might not be showing the effects of a previous cross, he pollinated some of the plants of the yellow sort with their own pollen and obtained ears, all the kernels of which were exactly like the mother grains. On the other hand, two ears obtained by fertilizing the yellow sort with pollen of the dark brown sort had about half of the kernels like those of the mother sort, or a little lighter, while the other half, scattered about among them, were a dirty violet color. On these latter, therefore, the pollen of the brown-kerneled sort had exercised a direct transforming influence."

Numerous other experiments have been made in this country on the subject of the immediate influence of foreign pollen

*Year book U. S. Dept. of Agr. 1897: 404-405.

Fig. 45H. Spelts and Einkorns Experimental Plats, Garrett Pk., Md. 1, spelts; 2, einkorn; 3, engrain double; 4, spelts. (Carleton, Div. Veg. Path. and Phys., U. S. Dept. Agrl.)

Fig. 451. Composite cross, showing samples of the last cross. (Redrawn from Trans. Highl. and Agric. Soc. of Scotland. Carlton, Div. Veg. Path. and Phys.)

on the kernels. The literature is given quite fully by Kellerman and Swingle.*

Webber† says: "In the writer's experiments it was found that the plumbeous or blueish-black color of the aleurone layer of the endosperm in the cuzco and Black Mexican races was apparently shown in almost all cases as xenia when these races were used as the pollen parents in crossing with white or yellow races of Dent, Flint or sweet corn. In all of the cases observed by the writer no exception has been found to the rule first asserted by Koernicke, that xenia is shown only in the endosperm, the portions of the kernel outside of the endosperm remaining unaffected."

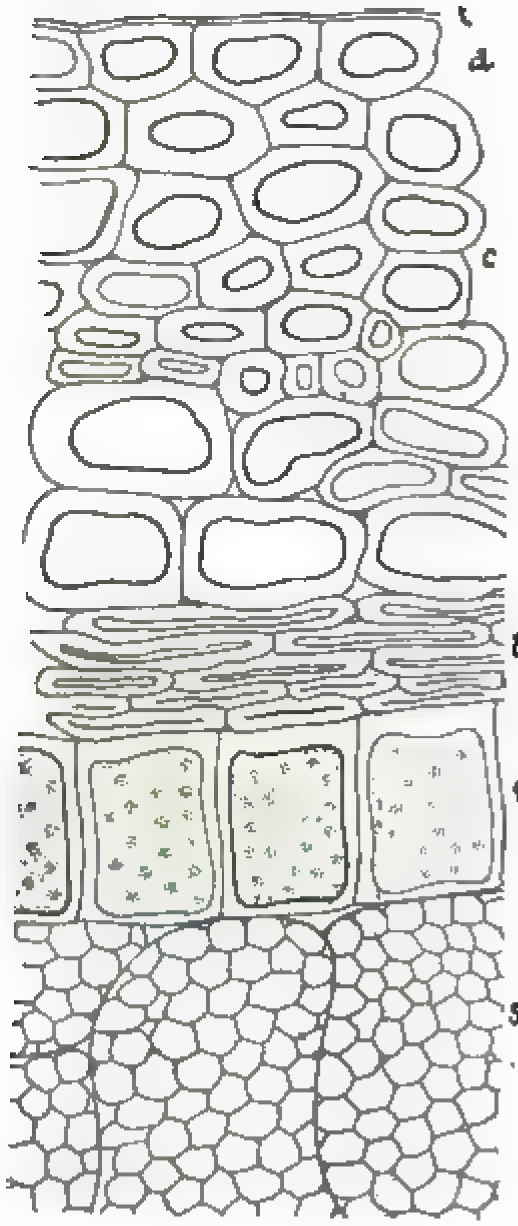

Fig 47. Caryopsis of Mexican corn, popcorn type; *a*, epidermal cells of capsule; *c*, capsule; *t*, testa; *d*, aleurone cells; *s*, starch layer. (Pammel and King.)

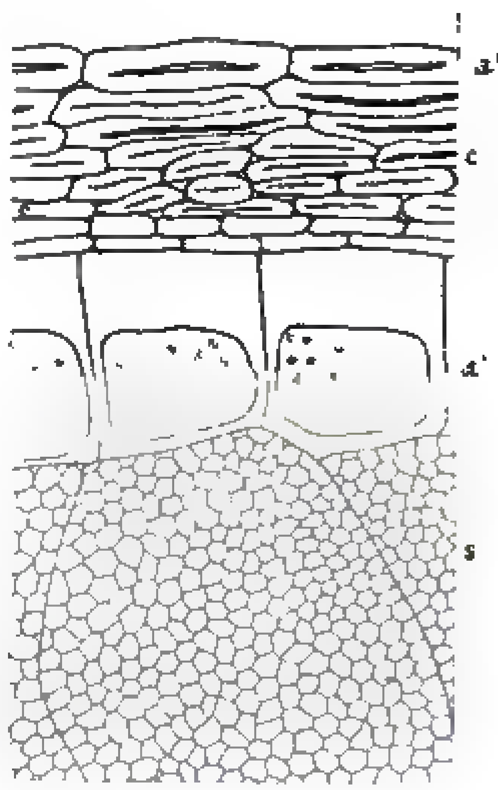

Fig. 48. Maize caryopsis; *a*, epidermal cell of caryopsis; *c*, caryopsis below testa; *d*, aleurone layer; *s*, starch layer. (Pammel and King.)

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*Experiments in Crossing Varieties of Corn. ;Bull. Kan. State Coll. Agr. Exp. Sta., 17: 151-174. pl. 5, and Ann. Rep. Kan. Agrl. Coll. Exp. Sta. 2:

†For literature, see valuable paper by Webber. Bull. U. S. Dept. Agrl. Div. Veg Path. and Phys. 22: 1900.

Caryopsis or fruit.—The fruit in grasses is called a caryopsis. The thin pericarp or capsule is closely connected with the seed. Physiologically the pericarp takes the place of the testa, being well and strongly developed, while the testa is only feebly so. In general the structure is as follows: The epidermal layers, thinner walled parenchyma and a delicate fibro-vascular bundles. Bran consists of the testa and capsule with the adjacent layer, the nucellus when present and the endosperm. It should also be observed that the pericarp often unites with the bracts, especially palet, but seldom to the flowering glume as in barley.

Dr. Rodney True* summarizes his work on development of cereals as follows:

I. In corn, wheat and oats, at the time of fertilization the single ovule is furnished with two integuments which are more or less complete. As development proceeds (1) the outer integument soon disappears; (2) the inner cells of the wall of the ovary are absorbed, in varying proportions; (3) the tissue of the nucellus is absorbed, with local exceptions.

II. At maturity these remain as seed covering: (1) The external portion of the wall of the ovary in varying proportions, forming the pericarp; (2) the inner integument persisting in a state of compression. The epidermis of the nucellus also persists, though much compressed.

III. Late in the development of the fruit, the remaining (inner) integument becomes soldered to the adjacent inner cells of the pericarp, forming the fruit correctly described by Mirbel under the name of "cerium" and rechristened by Richard the "caryopsis."

Zea mays L. In another connection one of us has discussed the structure of Zea.† The pericarp consists of thick-walled epidermal cells followed by a layer of variable thicknesses, the walls of which are greatly thickened, with radiating pore canals. The testa is insignificant, the walls are thinner than in pericarp. Remmants of the nucellus may be distinguished in some parts of the seed. This is followed by the endosperm. The aleurone cells are smaller, very different from those underlying it. The starch cells following the aleurone are closely packed and filled with angular starch grains.

Avena sativa L. In common oats the caryopsis is slightly

*Bot. Gazette, 18: 214 pl. 24-26.

†Proc. Ia. Acad. of Sci. 5: 199.

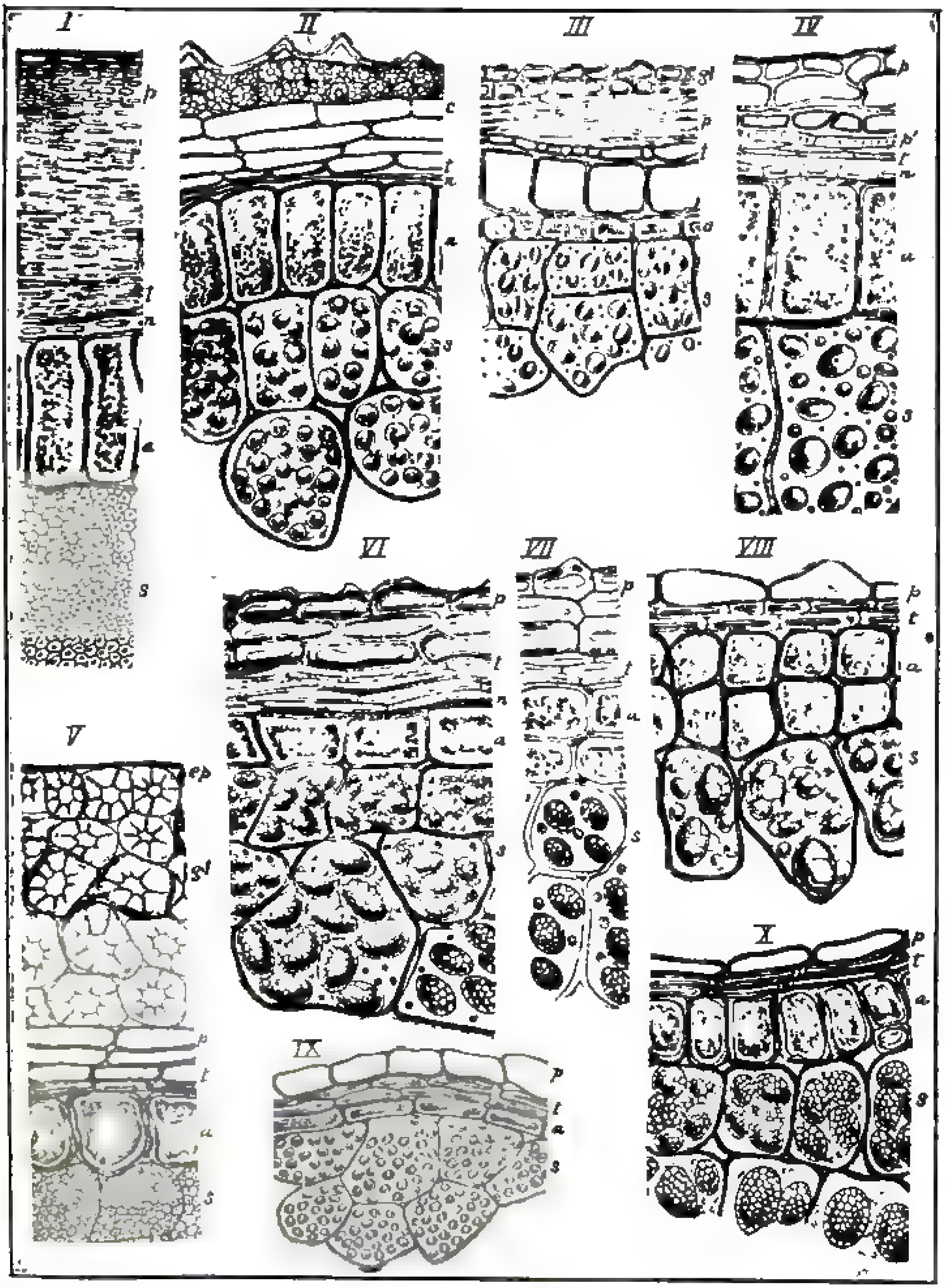

Fig 48 I. *Zea Mays:* nucellus a single row of cells, pericarp much more developed than the testa. II. *Hordum jubatum:* thick-walled sclerotic cells of glume with short trichomes above the caryopsis; c remnant of nucellus III. *Sorghum vulgare* var. *communis* (*Andropogon. Sorghum* var.): small aleurone cells; simple spherical or elliptical starch grains. IV. *Secale cereale:* large spherical or somewhat elliptical starch grains; nucellus a single row of cells; p porous thickened walls of pericarp. V. *Euchlaena mexicana:* starch grains solidly packed together. VI. *Avena sativa* pericarp with irregular cells on surface, the minute "down" of seed; a single row of cells to aleurone layer; in VII same, showing more than one row, starch grains compound. VIII *Arrhenatherum avenaceum:* aleurone layer of two rows of cells: starch grains compound IX *Phleum pratense:* lower figure, general view cross section of seed with embryo in position. X. *Poa pratensis*. large compound starch grains in endosperm.

hairy. The large epidermal cells are thick-walled, slightly irregular on the surface, followed by several rows of thick-walled cells in a general way much like the epidermal cells. The testa consists of a much compressed layer mostly of two rows of thick-walled cells; remnants of the nucellus evident. The aleurone layer of the endosperm consists of one or two rows of cells; the outer portion of the starch cells contains less starch than the inner. The starch consists of large compound grains, the component parts five to six-sided.

Secale cereale L. An excellent account of the structure of this fruit will be found in the works of Harz, Tschirch & Oesterle, Tietschert, Gregory and other writers on economic food products. Literature of the whole subject is given fully in a paper by Pammel.*

The pericarp consists of tangentially elongated epidermal cells with large cavities. The outer wall is thickened as well as the inner, the lateral walls thinner. Harz states that there is an important distinction between *Secale* and *Triticum;* a somewhat analogous structure, however, occurs in the spelts The epidermal layer is followed by smaller thin-walled parenchyma cells. The layer next to these parenchyma cells is frequently composed of thick-walled porous cells with pore canals. These cells not evident except in mature fruits. The testa is but slightly developed and consists of comparatively small cells frequently colored brown. The nucellus occurs as a remnant especially in the groove, where the cells are thick-walled and somewhat gelatinous. The endosperm resembles that of wheat. The aleurone layer consists of a single layer of cells. The exterior walls are greatly thickened. The cells of the starch layer large, containing a large number of round or elliptical starch grains, extremely variable in size. The starch grains on the whole are larger than those of the genus *Triticum.*

The adhering palet consists of several rows of thick-walled cells. The epidermal cells are longer and somewhat thicker-walled. The cells below are also thick-walled, provided with pore canals. In places the epidermal cells develop into a short trichome. Underneath the thick-walled cells occur several rows of thin-walled irregular parenchyma cells. The

* Pammel. Histology of the Caryopsis and Endosperm of some grasses. Trans. Acad. Sci. of St. Louis, 8: 199. *pl. 17–19.* Proc. Ia. Acad. Sci., 5: 199, 1897. Contr. Bot. Dept. Ia. St. Coll. Agr. and Mech. Arts, 10. 1, 1898. Hays and Boss, Minn. Agr. Exp. Sta. Bull. 62: 418. Bolley, Bull. N. D. Agr. Exp. Sta. 9: 1.

pericarp follows. It consists of several rows of thick-walled translucent cells, the cavity being very much reduced. The testa is colored brown. The cells are tangentially elongated and the cell-walls are thinner. The nucellus is very much reduced excepting in the groove, where it occurs as thick-walled cells. The endosperm differs in a very marked degree from either that of Triticum or Secale, especially the aleurone, which consists of three to four or exceptionally more rows of cells. The starch cells are much larger and contain large spherical or elliptical starch grains, accompanied by numerous smaller ones. Small protein grains are abundant.

Structurally there are wide differences between the tribes of the order, very marked in some closely allied genera. The pericarp is well developed in such genera as Zea, Arundinaria, and fairly well in Triticum, Secale, Hordeum and Avena. The testa is but slightly developed in most cases, notably so in Festuca, *Panicum glabrum*, Aristida and *Oryza sativa*, the protective features being provided for by the glumes surrounding the fruit, or the wall of the ovary. The nucellus is never entirely absent, especially in the groove. It is usually much compressed. In the genera Festuca and Bromus, the cells are large, thick-walled and mucilaginous, and no doubt act as reserve food. The aleurone layer is variable. It is never absent. Of one row of cells in Triticum, Zea, Zizania. The cells are very small in *Panicum crus-galli*, Aristida, *Setaria italica*. Of more than one row of cells in Avena, Arrhenatherum, Festuca, and *Hordeum vulgare*. The starch cells differ in size and contain small spherical or elliptical grains in *Sorghum vulgare* and *Cenchrus tribuloides*. Large spherical or somewhat elliptical grains occur in Triticum and Hordeum, accompanied by numerous smaller ones. Small five or six sided grains in *Panicum crus-galli*, *Zea mays*, *Euchlaena mexicana*. This applies in general to the tribe Maydeae and Paniceae. Cenchrus is, however, an exception to the rule. Compound starch grains occur in Zizania, Oryza, Avena, Arrhenatherum, Glyceria, Poa, Phalaris and Arundinaria; most grasses appear to have compound grains. The endosperm always contains protein, though much reduced in the starch cells, except in the aleurone layer, where no starch occurs. The starch cells next to the endosperm contain more protein than the interior of the endosperm. Fat is also present in small amounts. The com-

pound starch grains of Nardus in the tribe Hordeae are somewhat anomalous.

Specific gravity.—Little work has been done in this country on the specific weights of our seeds. Such studies have been made of European wheat by Harz, Nobbe, Koernicke and Werner and others. Several years ago Pammel and Stewart made some determinations indicating the difference in wheat in this respect and that a study of the specific gravity and number of seed per pound and bushel of considerable interest and commercial importance.

Wolfenstein gives the following figures with reference to wheat:

Summer wheat, Halle, Germany	1.3884
English wheat, England	1.4134
Purple straw wheat, Australia	1.4011
Tuscan wheat, Australia	1.4156
Siberian wheat, Siberia	1.4149
Michigan Amber, Michigan	1.4292

Climate and soil both greatly modify the weight and character of the seed. This variation is also great in different varieties. To compare the results obtained from these studies a few figures are taken from Harz. One hundred seeds of the following varieties weighed as follows: Prince Albert, 5.102 grams; Archer's Prolific, 4.298 grams; Hunters wheat, 3.714 grams; Mediterranean wheat, 4.532; White Genesee wheat, 4.403 grams.

Some tests made by Pammel and Stewart* with wheat from various localities in the United States gave the following results: World's Fair, Seneca Falls, N. Y., 1.146296; Winter Fife, La Crosse, Wis., 1.44578; Martin Amber, La Crosse, Wis., 1.35054; Golden Cross No. 2, 1.47524; Bissell, Manhattan, Kan., 1.4765; Turkey Red, Manhattan, Kan., 1.441; Missogen, Berkley, Cal., 1.480; Carter's Hundredfold, Berkley, Cal,, 1.518; Fultz, Raleigh, N. C., 1.489; Red May, Raleigh, N. C., 1.454; Turkey Red, Iowa, 1.43727. According to Wolfenstein, as quoted by Nobbe, the lowest specific gravity out of the thirty samples, occurs in white wheat (Saxony), 1.3766. An average sample of Bohemian wheat from the market, consisting of three varieties had a specific gravity of 1.4208. The highest specific gravity recorded is 1.4396, Ohio Red.

* Bull. Ia. Agrl. Exp. Sta. 25: 26.

It is interesting to compare the specific gravity of wheat with that of a few other seeds obtained in Europe. An average sample of corn has a specific gravity of 1.147; Castor Oil bean, .908; Buckwheat, 1.104; Field pea, 1.355; White clover, 1.41; Kale, 1.35; Rutabaga, 1.38.

Schulte and Wright in the botanical laboratory, Iowa State College of Agriculture and Mechanic Arts, determined as follows concerning the weights and specific gravity of several cereals. Corn: Giant White Dent, 1.2547; Hickory King, 1.2932; King of Earliest Dent, 1.3284; South Dakota Flint, 1.3367; Mastodon, 1.2712; Jumbo, 1.2352; Chester County Yellow, 1.2753; Common Yellow Field, Iowa grown, 1.2826; Common White Field, Iowa grown, 1.3627; Golden Cable, Missouri, 1.2821; Pride of the North, 1.2766; Iowa Gold Mine, 1.2836; Longfellow Flint, 1.3044; Iowa Beauty, 1.2816; White's Mammoth Red, 1.2511; Monarch Rice popcorn, Iowa, 1 3550; Red Beauty popcorn, 1.3738; Hickory King, Alabama, 1.3088; Pride of the Farm, 1 3306; Alabama Yellow, 1.2022; Hickory King, Kansas, 1.2555; Improved Leaming, Kansas, 1.2945. Wheat: Turkey Red, Iowa, 1894, 1.3290; 1895, 1.3065; Fife, 1894, 1.4177; Red Clawson. Missouri, 1894, 1.3594; O'Kangan Valley Velvet Chaff, 1.5197; Wisconsin Triumph, 1.4077; Turkey Red, Kansas, 1894, 1.3659; Turkey Red, Iowa, 1.4137. Oats: Nameless Beauty, Wisconsin, 1.3432; Giant Yellow, Wisconsin, 1.3178; White Bonanza, Wisconsin, 1.3290; Red Rust Proof, Kansas, 1.2550; Full Moon, Iowa, 1.2302; New Salt Lake, Iowa, 1. Clover: Iowa, 1.2121; White Superior Scotch, 1 2334; Black Mammoth Cluster, Wisconsin, 1.1257; Wide Awake, Wisconsin, 1.1892.

Mr. J. U. Loyd,* who has made an exhaustive study of the grain weight, records the following densities: Duluth Hard Springs, 1.394; India, No. 1 Club Bombay, 1.385; Manitoba Spring Hard, 1.388; Ohio White Winter, 1.387; Black Sea, Azima, Russia, 1.383; Patagonia, South America, 1.380; Wisconsin Spring, 1.377; Australia, 1.377; Ghirka, Fine Russia, 1.364; California No. 1, 1.358; River Platte, South America, 1.357; England White, 1.346; New Zealand White, 1 346; Odessa, Russia, 1.343; Chili, 1,332; England Red, 1,337; Washington State, 1.327.

According to the same investigator 100 grains of wheat of the following varieties weigh as follows: New Zealand White,

*The Grain Weight: A study of wheat. Cincinnati. 16.

77.9; England Red, 77.4; No. 1 Club Bombay, 84.2; Baltic, Rus sia, 56.6; Ghirka, Fine Russia, 49.3; Chili, South America, 77.9; Ohio White Winter, 51.4; Wisconsin Spring, 47.4; Duluth Hard Spring, 46.7; River Platte, South America, 46.1; California Choice, 74.4; Manitoba Hard Spring, 43.9.

Messrs. Schulte and Wright determined as follows concerning the number of grains in a gramme: Corn: Giant White Dent, 3.4; Hickory King, Wisconsin, 2.0; Common White field, Iowa, 3.5; Eclipse, Wisconsin, 3.2; Iowa Gold Mine, 2.9; Hickory King, Iowa, 2.1; Improved Leaming, Iowa, 2.9; White's Mammoth Red, 2.9; Red Beauty popcorn, 8.3; Monarch Rice, 11.6; Hickory King, Alabama, 1.9; Alabama Yellow, 1.8; Stowell's Evergreen, Iowa, 4.1. Wheat: Turkey Red, Iowa, 40; Red Clawson, Missouri, 23; Fultz, Missouri, 29; Wisconsin Triumph, 39; Turkey Red, Kansas, 32; Currell, Kansas, 35. Oats: Giant Yellow, Wisconsin, 27; Red Rust Proof, Kansas, 35; New Salt Lake, Iowa, 45; Black Mammoth Cluster, Missouri, 39; White's Superior Scotch, Iowa, 33; Lincoln, Iowa, 40.

In 1893 wheat, obtained from various sources, gave the following results: New York, La Crosse, Wis., Jones' Winter Fife, 37.3; Wisconsin Triumph, 33.5; Iowa Turkey Red, 35.92; New York, Red Clawson, 22.77; World's Fair, 26.92; Golden Cross No. 2, 24.077; Bissell, Kansas, 28.77; McPherson, 33; Turkey Red, Kansas, 33.77; Missogen, California, 18; Carter's Hundredfold, 23.233; Fultz, North Carolina, 34.933; Early Red Clawson, 31.28; Amber, 28.6.

One hundred seeds of Michigan Amber weighed 3 5134 grammes. Purple straw, 6.864; English wheat, 3.7798; Summer wheat, Halle, 2.8654.

Schertlen gives the following specific gravity of some grass seeds: *Muhlenbergia mexicana*, 1.100; *Arrhenantherum elatius*, with chaff; 0.600; *Avena sativa*, 1.345; *A. orientalis*, 1.021; *Bromus inermis*, 0.746; *Holcus lanatus*, with chaff removed, 0.301; *Hordeum vulgare*, with chaff, 1.351; *Panicum miliaceum*, 1.179; *Zea mays*, 1.147.

Dissemination.—An important step in the life of every plant is the dissemination of its seed, since without this the species has little chance to perpetuate itself.

Grasses are disseminated by wind, animals, hygroscopic movements, water and man.

Speaking of dissemination Hackel says: "In all wild grasses certain parts of the spikelet or of the entire inflor-

escence fall off with the fruit. If the spikelet is many-flowered and every flower ripens its fruit, then its axis breaks into as many pieces as there are fruits, and every piece carries a floral glume and palea. If the spikelet is one-flowered, the axis of the spikelet may separate above the empty glume, so that the floral glume and the palea fall off with the fruit (Agrosteæ); or it may divide below the empty glume, and the spikelet fall off as a whole (Paniceæ, Andropogoneæ, etc.). If the spikelets form a spike or a raceme, it frequently happens that the latter divides so that one spikelet falls off with each joint (many Andropogoneæ and Hordeæ); short spkes (*Triticum ovatum* Godr.) fall from the culm as a whole. All these arrangements are necessary for the distribution of the seed; they are lacking (with two exceptions) in all cultivated cereals, but are present, on the contrary, in all native races of the same species, so far as these are known. Since these arrangements are very disadvantageous for the complete gathering of the fruit, varieties whose axes are less or not at all articulated will be preferred in culture, and will be finally fixed by natural selection."

Seeds to be disseminated by the wind must be sufficiently light. Surrounding the fruit are bracts, which diminishes the specific gravity. *Hordeum jubatum*, and Agrostis are carried by wind because of their lightness. In many grasses copious hairs are developed either as parts of the sterile glume or parts of the axis. In Andropogon the rachis or both rachis and the sterile flowers are provided with long hairs. In Phragmites the base of the flowers are silky villous and with a conspicuous silky-bearded rachis.

In Calamagrostis the callus of the flowering glume is provided with short or long hairs. In Poa the principal veins of the flowering glume are cobwebby (figure 36). The seeds readily adhere to woolly objects, or they may be carried by the wind.

The beautiful European *Stipa pennata*, and our variety, *neomexicana*, are well adapted for wind dissemination. Its long plume makes it easy for the wind to carry.

The wind, however, acts in other ways. The Australian Rolling Spinifex forms a large round head. This breaks away and rolls over the dry sands of Australia until it is carried to a dry place, when it expands and soon takes root. In tickle grass (*Panicum capillare*) the whole inflorescence breaks away

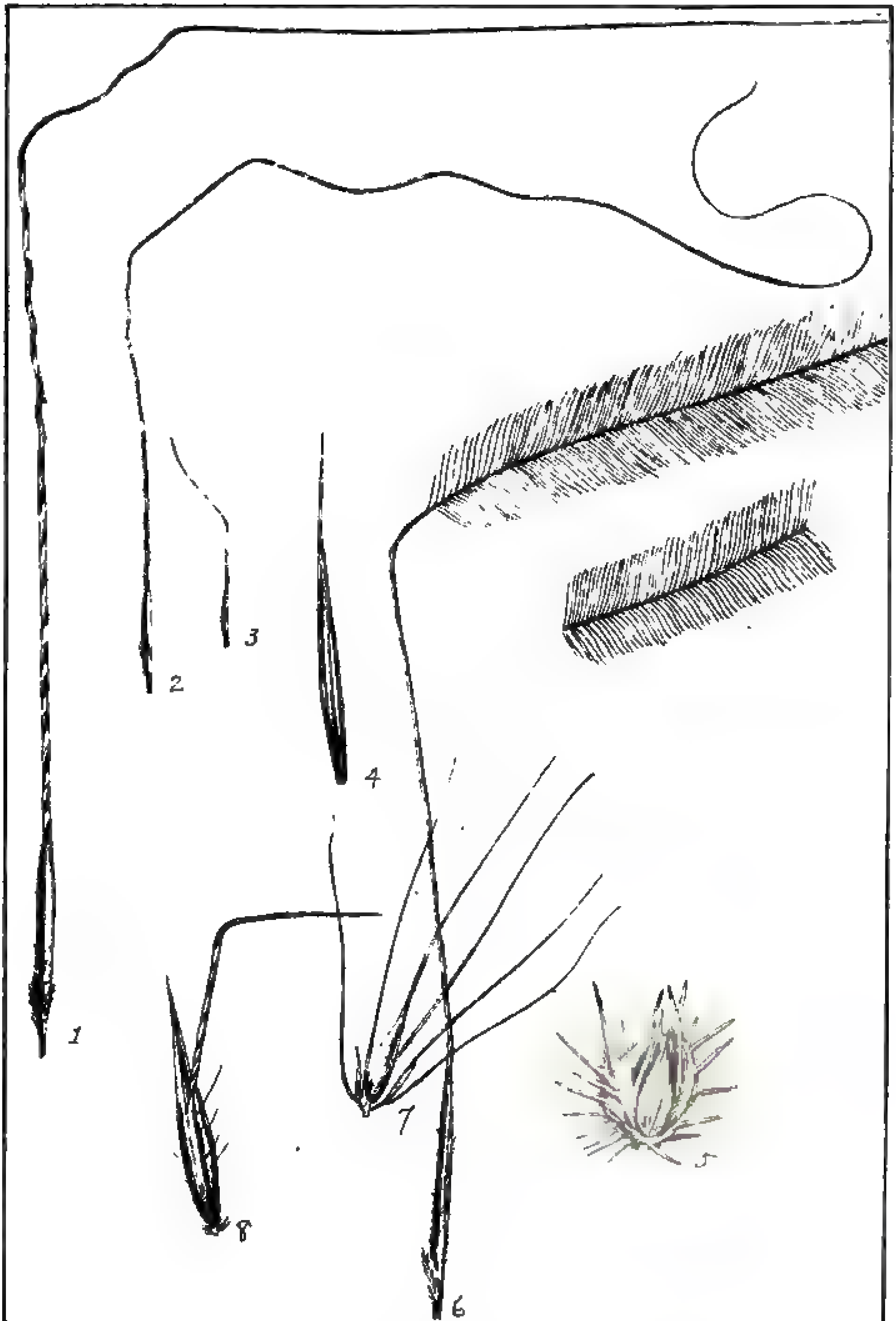

Fig. 49 Dissemination of grasses. *1, Stipa spartea*, twisted awn and hairs, self-burying "seed;" 2, *S. comata; 3, S viridula; 4, Zizania aquatica*, a floating "seed;" *Cenchrus tribuloides*, with a bur for attaching itself; 6, S. *pennata*; 7, *Hordeum jubatum*, animal dissemination; 8, *Avena fatua*, a "seed" with hygroscopic characters. (King)

and is either bodily carried up in the air or rolls along the ground. Many of our native grasses like Eragrostis are carried in a similar way. To be sure, many of the seeds fall long before they separate from the plant. And yet dozens of fruits may be counted on a single panicle. The wind may also carry the seed over the snow during winter.

Animals and hygroscopic movements.—Animals are most efficient in conveying the seed of many grasses. The stiff, sharp spines of the involucre in Sand Bur (*Cenchrus tribuloides*) are most efficient in piercing the skins of animals. Indeed it sometimes causes considerable annoyance to animals and man. In Streptochaeta, says Hackel, "The ripe fruit hangs from delicate spiral threads (the awns) which are fastened together at the end of the spike; they are free below, and their soft-pointed bracts, bent outward, act like fish-hooks by catching into the fur of any animal that touches them in passing."

Our common Squirrel-tail grass (*Hordeum jubatum*) is most efficiently carried by animals. The spikes, when mature, break up into joints, and although the joints are not sharp-pointed they readily cling to the fleeces of animals. So, too, do the broken points of Sitanion cling to animals.

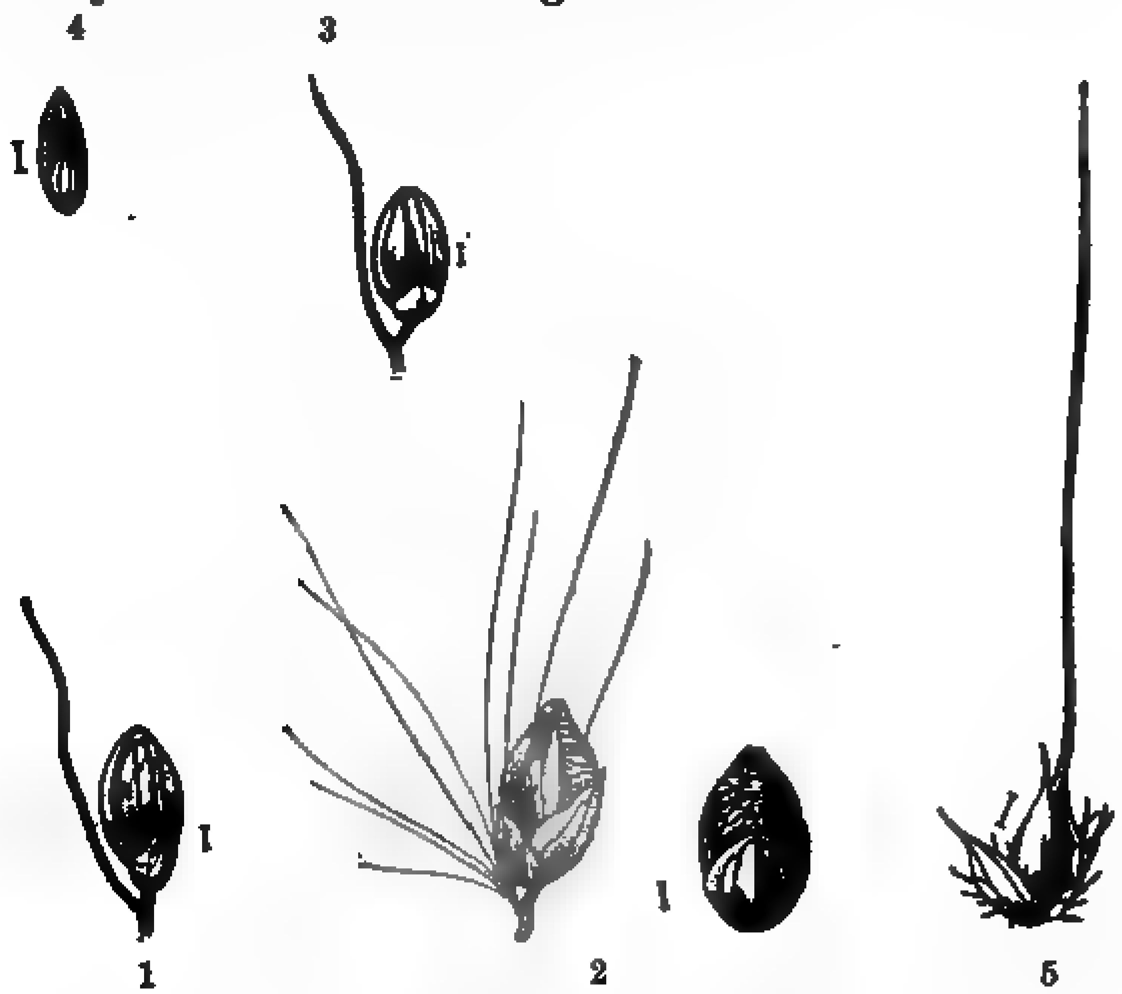

Fig. 50. *1*, Foxtail (*Setaria viridis*); *2*, *Setaria glauca*; *3*, *Setaria verticillata*. The seeds of all three species carried by animals, especially sheep and cattle. *4*, *Panicum sanguinale*; *5*, *P. crus-galli*. The seeds of these are carried by birds, used as food.

A most interesting case of animal dissemination is afforded by a native species of *Stipa spartea*. The cylindrical grain is provided with a sharp-pointed cullus which makes it easy to penetrate clothing, the skins of animals and soil. The grain is enclosed by the hard, persistent, flowering glume which surrounds the palet. The lower portion of the coriaceous flowering glume, as well as the pedicel, are covered with stiff hairs that point upwardly in an oblique direction. The flowering glume bears a strong awn twisted like a rope. This awn is very sensitive. The coils unroll or unwind when damp, and

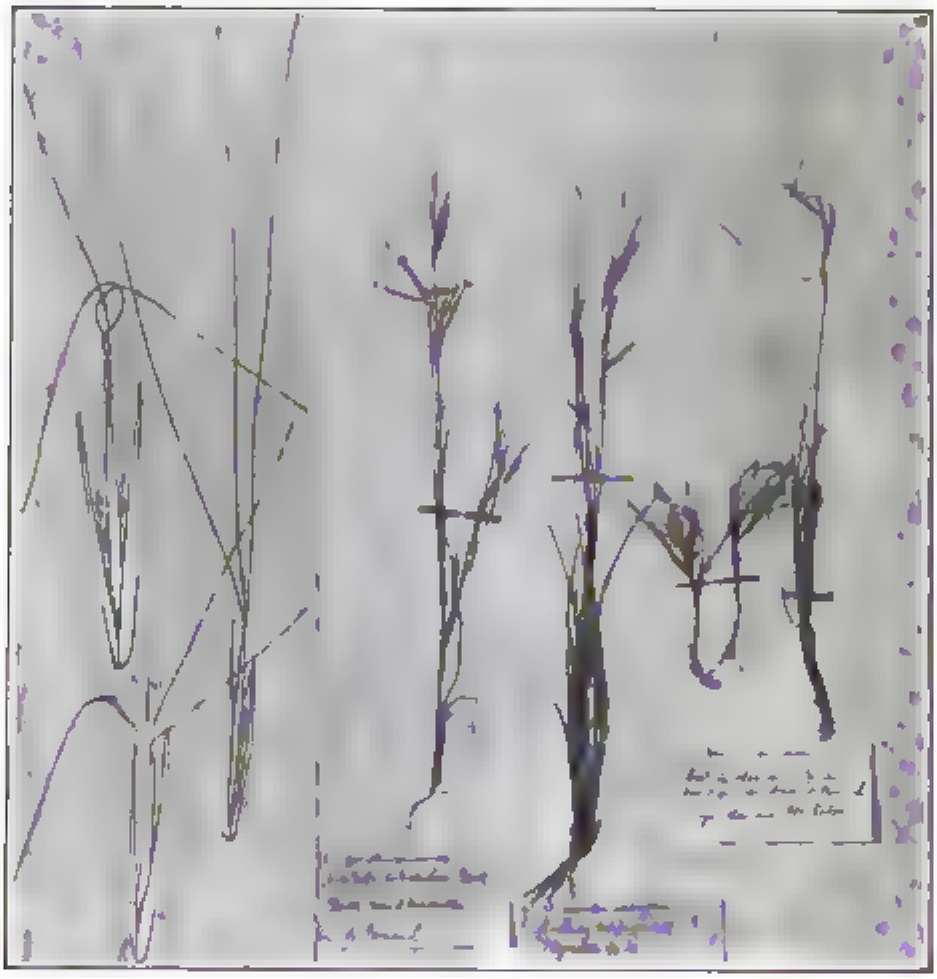

Fig. 51. Dissemination of Aristida. *Aristida tuberculosa*, awned flower, lower detail; *Aristida purpurea*, awned flower, detail at the right; *Aristida oligantha*, awned flower, detail at top.

when dry they return to their former condition. Whenever this drying-out takes place the points of the flowering glume are rotated with lateral variations. The upper half of the awn remains straight and soon becomes bent at nearly a right angle to the twisted part. This portion of the awn is of very material assistance when it comes in contact with surrounding objects. The bristles at the lower end prevent the seed from being pulled out. "This rotation and nutation, together with the action of the bristles, soon causes the bract surrounding

the fruit to bore deeply into the ground." This boring into the soil takes place in a short time. Beal says, in speaking of the Feather grass (*Stipa pennata*): "Francis Darwin found that the rate increases up to the fifth revolution, and then diminished quickly. In three wettings and three dryings, a little over an inch was buried in dry sand. A rise of temperature affects the awns in the same way as increased moisture; a fall of temperature acts like dryness. Mr. Darwin found that minute strips of the awn, consisting even of two long cells, twisted just as well as the entire awn. He thinks that the torsion is produced by the striation or stratification of the cell walls. These are a series of parallel lines, alternately light and dark, traversing the surface of the cell. Very frequently the two systems wind spirally round the axis in opposite directions. When the tissue expands during the absorption of water, it is due mainly to the swelling of the less dense striæ. This is thought to be the cause of torsion in cotton wool. Soon after being buried, where the soil is moist, the awn breaks off at a joint from the apex of the grain."

Mr. R. M. Christy states that a large number of the seeds are often found beneath the skin of sheep, especially about the shoulders. Dr. M. Stalker states that in many of the northwestern counties of Iowa they occasion much annoyance to sheep, and, in some instances, cause the death of animals. They penetrate and bury themselves in the flesh. Dogs, and even persons, are also affected. F. H. King says that he was much annoyed by the fruit of this grass. *Stipa capillata* of southern Russia, *Aristida hygrometrica* of Queensland and *Heteropogon contortus* of New Caledonia inflict similar injuries.

The beautiful south European grass (*Stipa pennata*) also buries itself in the soil. The long, feathery awn enables the wind to carry it away. The "seed" is small, the flowering glume has a pointed callus and above it obliquely pointed stiff hairs. As in the other species it is provided with strong, twisted awns that end in a long, beautiful feather. As the seeds are carried by the wind they eventually fall, with the "seed" end to the ground, as it is heavier at the lower end. The "seeds" remain in this position as long as dry, but when moist the spirally twisted awn unwinds the plume and helps to hold it in the soil; thus, finally, the "seed" is buried in the ground.

Several species of Avena, *A. barbatum* and *A. fatua*, our wild oats, are similarly provided with twisted awns that help to bury the seed. Several species of Aristida also bury themselves, as do members of the genus Danthonia. In *Triticum ovatum* the entire spike falls off. It possesses a very pointed base, and the numerous rough awns pointed outward, thereby movements of the wind exert a pressure upon the point which drives it into the ground.

The peculiar use of the awns of *Avena sterilis* are described by Hackel as follows: "Two strongly awned fruit-bracts fall off, fastened together; in moist surroundings the twisted awns begin to rotate their diverging upper halves, consequently they cross and press against each other until the bracts are forcibly separated, thus giving the fruit an impetus which throws it off for some distance.

In many cases seeds of grasses are distributed by birds and animals which feed upon them but do not digest them. Birds of various kinds freely feed upon *Setaria glauca*, *S. viridis*, *Panicum miliaceum*, often carrying them great distances. Many herbivorous animals also help to carry seeds in this way, as is evidenced by seeds of many grasses that come up from excreta. This manner of distribution for most seeds is a most precarious one, as the "seeds" pass through the digestive canal, germination is hastened, and thus they may be destroyed. But the fleshy berries of many Bambuseæ are especially adapted to animals which do not destroy or digest the seeds. Many animals, especially wading birds and others, carry seed of grasses in the mud that clings to their feet.

The light specific gravity of many grass fruits make them especially susceptible to dissemination by water. The chaff, in many cases, remains persistent, and so constructed that the whole floats readily. Thus rice and wild rice will float for a time until they are soaked with water. Water, however, adds mostly in a mechanical way, currents of water carrying away large quantities of earth with which are mixed seeds of grasses. Neighboring farms have frequently been sown with seeds of wild oats in this way, as has been witnessed in many cases along the bluffs of the Mississippi in Wisconsin and Minnesota.

Certain fruits of grasses are thrown out by expulsion. Professor Beal says of Sporobolus: "The ovary of Sporobolus is very thin and tender. Free seeds may often be seen still adhering to various portions of the glumes and branches of the

panicle. One of my special students, at my suggestion, has made a few experiments to determine the mode in which the seed escapes. Inside the ovary and about the seed there is a gummy secretion. When about ready to escape or at a certain stage of maturity, if water be applied to the panicle, in a short time the seeds come forth. A part of the panicle was wet and in thirty minutes twenty-seven seeds escaped. In another case the seed began to escape in ten minutes after the water was applied. After drying six days in a room seeds started out in twenty minutes after wetting. In other cases seeds have been seen to escape in six minutes and in one case in four and one-half minutes. If the ovary is carefully removed from the floral glume and palea and water is applied, the seeds usually escape a little quicker than when left in the floret."

"On applying water the ovary may be seen to slowly enlarge, till it bursts and the seed pops out in a hurry. If a little water is applied, it moves more slowly, and if the glumes are still near the ovary the seed moves upward and usually adheres to some part of the panicle. A slight sprinkling or a heavy dew would bring the seeds out, but a heavy rain would wash them down at a time when the condition would be favorable for germination. Several other species, as I judge from herbarium specimens, expel and hold their seed in a similar manner. The action of the water on the ovary seems to be purely mechanical and is explained in well known works on physics. The water enters the ovary faster than the gum can escape. The ovary is flattened and splits on the side next the palea." The gum spoken of by Beal is a mucilage and resides in the outer walls of the cells of the capsules that swell on the addition of water.

Man, too, is an agent in the scattering of the seeds of grasses and the introduction of new seeds. Certain grasses most commonly follow the culture of certain grains, as chess and its occurrence in wheat fields.

It is a well known fact that chess is more abundant where wheat is extensively cultivated, and there is no question that this weed was introduced by the wheat seed brought from Europe Darlington* observes, "This foreigner is a well known pest among our fields of wheat and rye and occasionally appears in the same field for a year or two after the grain crop. Years ago it was observed that this weed was common

*American Weeds and Useful Plants. Revised by George Thurber. New York. 886.

along the roadside, the seed of this weed having been scattered from the farmers' grain wagons." *Lolium temulentum* is another well known illustration where man has acted as a disseminator. This weed was well known to the ancients as a serious pest in grain fields. This weed seldom occurs in this state now. Formerly it was much more common, when Iowa was a wheat-growing state.

The sand-bur affords another excellent illustration of man as an agent in scattering seeds. During the early days, sand-bur was common along the sandy embankments of streams; now it has become common throughout the state of Iowa, and largely because the sand used for building purposes is obtained from the river bottoms. Then, too, it has been scattered far and wide by the railroads who use the gravel as ballast. *Setaria verticillata* has followed and occupied the waste places in many parts of this state, especially in the southern tiers of counties. It was largely introduced with foreign seed, or as a ballast weed in seaport towns. The common finger-grass (*Panicum sanguinale*) and pigeon-grass or fox-tail are largely disseminated through the use of clover and other agricultural seeds. Mr F. C. Stewart, some years ago, determined that it was the principal impurity in fifteen samples of red clover grown in various parts of this country. He says of it as follows: "The weed seed most commonly found in clover seed is *Setaria viridis*. This species appeared in fifty samples, *Setaria glauca* appearing but thirty-one times, *Panicum glabrum* twenty-four, and *Panicum sanguinale* three times." O. Burchard* reports that orchard grass in North America contains *Panicum capillare*, *Phleum pratense*, *Poa pratensis*, *Arrhenatherum elatius*, *Bromus erectus*, *Festuca pratensis*, *Holcus lanatus*, *Lolium perenne* and *Poa trivialis*. Burchard† further states that "almost every lot of red clover seed from the United States is found to contain, even when thoroughly purified, varying quantities of the following seeds: *Panicum crus-galli*, *Panicum filiforme*, *P. sanguinale*, *Panicum capillare*, *Phleum pratense*, *Setaria glauca*, and *S viridis*." We should observe, however, that some of the plants mentioned by this writer do not occur in clover seed, as, for instance, *Panicum filiforme*. *Bromus mollis*, a worthless forage plant, has been widely distributed as a weed, not only

*Contributions from botanical laboratory and seed-control station of Hamburg. 3: 1893. Abst. Exp. Sta. Rec. U. S. Dept. of Agrl. 5: 383.

†The objects and methods of seed investigation and the establishment of seed-control stations. Exp. Sta. Rec. U. S. Dept. Agrl. 4: 891.

because of its admixture in other more valuable forage plants, but its direct introduction as a forage plant. Johnson grass (*Andropogon sorghum* var. *halapensis*), has been widely distributed in the southern states since its introduction as a forage plant in South Carolina, about 1830, by Governor Means. Ten years later it was introduced into Alabama by Captain William Johnson. Since then it has been widely distributed throughout the south, where in some places it has become an execrable weed. It has advanced as far north as central Missouri, where it was introduced with seeds in part grown as a forage plant.

Another grass that has been distributed largely by human agencies is the Bermuda grass, introduced in this country first as ballast, from southern Europe. It has now spread over the entire southern states, and although a most valuable grass, is a dangerous weed when grown where not wanted. A few years ago we found, on the college grounds, the *Bromus tectorum*, the seed of which came with some packing material. Instances of this kind might be given much more extended notice in this connection. One other case is worthy of mention; Wild oats (*Avena fatua*), which has become widely distributed in Iowa, Wisconsin and Minnesota, occurring commonly as a weed in oat and wheat fields, but generally in oat fields. It is impossible to remove the seed of this species from oats. In the Rocky Mountain districts, wild oats is extremely common and this species was introduced in the same way. In California there are several pernicious species of Avena that were introduced with grain seed.

GERMINATION.

Structure of the embryo.—After the seed has been distributed, the next important step is germination. The small embryo is usually straight, rarely slightly bent with the radicle turned downwards. The following is taken from Hackel's excellent account: "Its most striking portion is the scutellum, which is regarded as the cotyledon. It is a flat but somewhat thick body, roundish to elongated oval in circumference, lying close on its inner side to the albumen, with the plumule and radicle surrounded by the coleorhiza situated in its somewhat shallow exterior. The plumule lies free upon the scutellum, but below the plumule the axis of the embryo is united with it. This is the point of insertion of the scutellum beyond which it projects downward and outward as far as the point of the coleo-

rhiza. This descending point of the scutellum is grown for a longer or shorter distance to the posterior part of the coleorhiza, so that they entirely unite in front or leave only a small cleft. If this is the case it is only in germination that the side portions are pushed back and the entire embryo becomes visible."

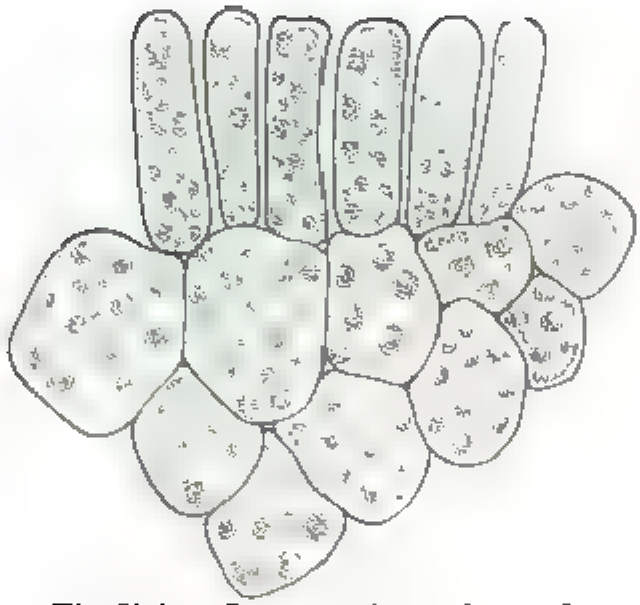

Fig. 51 A. Cross-section embryo of corn The cylinder epithelium above and large parenchyma cells below. (Pammel.)

The scutellum has a most interesting epidermal layer, the so called cylinder epithelium. These palisade-like cylindrical cells are thin walled and physiologically of great importance to the germinating plant. It is the function of these cells to absorb the dissolved, starchy substance of the endosperm. This cylinder epithelium is nicely shown in the germinating wheat. During germination the scutellum remains within the pericarp.

"In many grasses there is in front of the embryo and opposite the scutellum a small, scale-like appendage, the epiblast. It is especially clear in Stipa, and yet better developed in Zizania (where it is as long as the plumule), but it is entirely lacking in many grasses (rye, maize and barley); generally it is

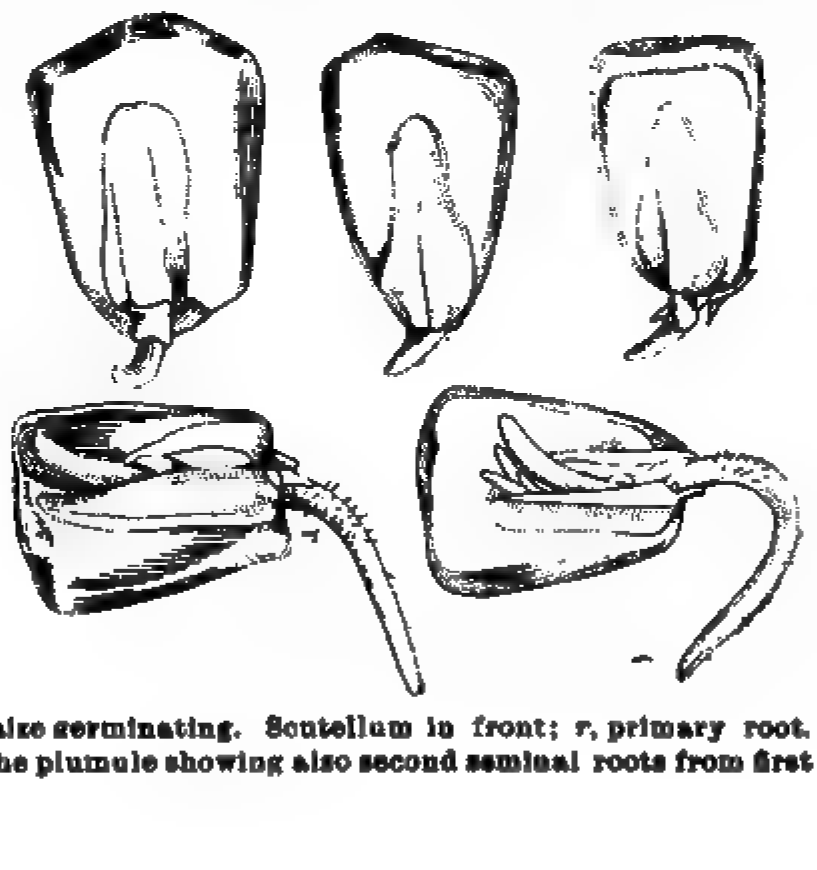

Fig. 52. Maize germinating. Scutellum in front; r, primary root. In lower left hand corner, the plumule showing also second seminal roots from first node. (King.)

Fig. 58. Squirrel-tail grass germinating, sterile spikelets, young plant and roots. (King.)

a delicate formation consisting of parenchyma without fibro-vascular bundles, and its morphological nature is still doubtful. Yet the view that it is the rudimentary second cotyledon is the most reasonable, for among other things this makes comprehensible the surprising position of the first leaf of the plumule of the embryo, consisting of a very short, often indistinct internode of the axis (epicotyl), and of two to four leaves, and according to the development of the former the plumule is sessile or petioled. The first leaf, the germ-sheath, surrounds the others like a closed tube, which breaks through the ground with its hard point at the time of germination, and opens at its apex after a time to allow the exit of the second leaf. It is colorless or pale green or frequently reddish. Many authors consider it a part of the cotyledon, a view which is certainly incorrect, for in many grasses it is separated from the scutellum at the time of germination by a distinct internode, which is often much elongated. In others this epicotyl is very short or entirely lacking, so that the back of the sheath may even be grown to the scutellum.

"The majority of grasses have only one radicle, and grow therefore with a primary root; in addition to which, especially from the epicotyl, new roots soon arise which finally exceed the main root in growth. In several grasses, especially in the cereals, and also in *Coix lachryma* and others, the foundation of these secondary roots is already laid before germination, usually in the hypocotyl (the axis below the insertion of the scutellum); seldom and only to a rudimentary degree, in the epicotyl. The planes of these secondary roots are parallel to

that of the scutellum; they can therefore be seen only in tangential and not in radial section of the seed. In germination, each rootlet independently breaks through the coleorhiza, which surrounds each with a small sheath. Before the roots break through, the elongating coleorhiza ruptures the pericarp and sends numerous hairs from its epidermis, thus fastening the somewhat superficially placed seed to the ground.

Physiology of germination.—It may be interesting now to discuss the physiological process of the germination of grass seeds. The food material made by the leaves is deposited in the seeds in the form of reserve material, consisting of two classes of substances, the albuminoids and carbohydrates. The amounts of these vary in different species. The manner in which the albuminoids are deposited varies, but they occur largely in the form of proteids, deposited in the form of aleurone grains.

The carbohydrates occur largely in the form of starch, though in some few cases reserve cellulose occurs, as in the perisperm of the seed of Bromus and allied grasses. An examination of the endosperm of grass seeds indicate that the outer layer of the endosperm consists of cells that differ in a marked way from the remaining cells. The researches of Haberlandt and several other writers have shown beyond a doubt, that this layer is a secreting organ in which ferments are produced which are transferred to the remainder of the endosperm, where the starch is converted to a sugar where it is taken up by the cylinder absorption epithelium, the outer row of cells of the scutellum.

The wide and universal distribution of the aleurone layer would appear to indicate some physiological purpose. Its function has been nicely demonstrated by Haberlandt and other writers.

Brown and Morris,* who have studied the germination of barley and a few other grasses, differ in regard to the digestive action of the aleurone cells. Haberlandt's work was carried out with rye, and as stated above indicate that the aleurone layer is a diastatic secreting tissue and that the aleurone layer does not entirely belong to the reserve food system. Haberlandt found the corrosion of starch grains first took place between the scutellum and the aleurone layer on the ventral side and this corrosion rapidly extended to the starch grains

*Jour. Chem. Soc. London. 57: 458.

on the dorsal side of the scutellum. It was also found that this corrosion of starch took place last of all in the groove. Haberlandt therefore concludes that the scutellum as well as the aleurone layer are secreting organs. To test this work, Haberlandt removed portions of the testa, including the aleurone layer, which had germinated to a certain degree. The second was washed with a brush containing one to two per cent sugar solution, placed upon moist filter paper with the aleurone layer upward. Upon the aleurone layer was placed a small quantity of moistened rye meal. The whole was then kept moist at a temperature of 18 to 20 C. In a couple of hours a corrosion of the starch grains had taken place. These sections were compared with others not so treated. In order to demonstrate this, Haberlandt cut around the edge of the scutellum and found that notwithstanding the break in the continuity of the aleurone layer and its complete separation from the embryo, it did not prevent the spread of the diastatic action, when these were later germinated. The inactive aleurone cell, according to the same investigator, contains no appreciable amount of diastase.

Brown and Morris, who investigated this question, state that they were at first inclined to believe as Haberlandt does, that the progressive action of the corroded starch grains were due to the special action of the aleurone cells. They further stated that the true explanation is due to the solution of the cell walls of the starch containing endosperm, but that this is a necessary preliminary to the dissolving action of the starch.

J. Gruss,* from a series of experiments on corn and several other plants, concludes that there exists in the germinated seed a soluble diastase which is capable of diffusion through the cell wall in the same way that sugar does. The removal of the cotyledons diminishes the amount of diastase in the stem. Brown and Morris state they found that the mother substance of the diastase secretion is probably derived from the endosperm. The form in which reserve starch enters the growing embryo has been found to be mostly invert-sugar, but there is also a considerable amount of cane sugar, as Kuhnemann† has shown. Later Kjeldahl‡ found that cane-sugar is

*Pringsheim Jahrb. f. wiss. Bot. 26: 379-437. *pl.* 2. 1894; Ber. Deutsch. Bot. Gesell. 13: 2-12. *pl.* 1. 1895.

†Ber. Chem. Gesell. 8: 202-387.

‡Rèsumè du Compt rend des travaux du Laboratoire de Carlsberg. 1881: 189.

present in barley and malt. The amount of cane-sugar in barley is given by O'Sullivan as follows:

Cane-sugar	2.8 per cent to	6.0 per cent
Maltose	1.3 " "	" 5.0 " "
Dextrose	1.5 " "	" 3.0 " "
Levulose	0.7 " "	" 1.5 " "

O'Sullivan concluded that the maltose was derived from the starch.

It may be interesting here to compare the percentage found by Brown and Morris.

	BARLEY AFTER STEEPING IN WATER FOR 48 HOURS.		BARLEY AFTER GERMINATION FOR 10 DAYS.	
	Embryos, grams.	Endosperms, grams.	Embryos, grams.	Endosperms, grams.
Cane-sugar	0.0204	0.0338	0.3430	0.1787
Invert-sugar	0.0070	0.0227	0.0174	0.1790
Maltose	....	....	....	0.3640
Total	0.0274	0.0565	0.3604	0.7217

	BARLEY AFTER STEEPING IN WATER FOR 48 HOURS.		BARLEY AFTER GERMINATION FOR 10 DAYS.	
	Embryos, per cent.	Endosperms, per cent	Embryos, per cent.	Endosperms, per cent.
Cane-sugar	5.4	0.3	24.2	2.2
Invert-sugar	1.8	0.2	1.2	2.2
Maltose	....	....	....	4.5
Total	7.2	0.5	25.4	8.9

These writers also conclude that the transformed starch is absolved from the endosperm by the columnar epithelium of the embryo in the form of maltose, and then is rapidly converted into cane-sugar. The main point of difference between the conclusions arrived at by Haberlandt and Brown and Morris are that the former believes that aleurone layer is largely a secreting organ. Brown and Morris say that the absorptive

epithelium columnar cells is a secretory tissue, and that there is no doubt that one of the special functions of these cells is the secretion of enzymes.

It was Sachs who first stated that the columnar epithelium was an absorptive layer, and most writers agree that this is one of its many functions, but Brown and Morris say that the absorptive function is secondary in its importance. According to these writers, when they had removed the columnar epithelium, the embryo developed when it was placed upon a culture medium containing a readily assimilable carbohydrate, such as cane-sugar or dextrose, just as it would have done in its unmutilated state, and when such a mutilated embryo is placed upon a starch gelatin mixture it entirely lost its power of corroding and dissolving starch granules. The secretion of diastase appears to be increased by the presence of the small quantity of acid, and its secretion is stimulated by the presence of digestible material, "that the flow of amylohydrolytic enzyme from the glandular cells of the scutellar epithelium might be influenced by the presence of starch, either in the granular form or as soluble starch." Starch does not stimulate the epithelium cells to increased secretion. It has been known for some time that the cell-walls of the endosperm end of a date seed become dissolved and is used for the nourishing of growing plantlets. This was shown very nicely by Sachs.*

This has also been abundantly proven for other seeds in which the reserve material is cellulose. Mr. J. R. Greene, who made a glycerine extract of the cotyledons of the date seed, concluded that the glycerine extract contained a trace of enzyme capable of converting cellulose into sugar. Brown and Morris have shown that during the early stages of germination the cell walls of the endosperm are disintegrated, and that the disappearance of the cell walls always precedes the attack upon the starch granules. That malt of barley contains an enzyme, to which they have given the name of cytohydrolytic as well as amylo-hydrolytic enzyme. The former when slightly assimilated and allowed to act upon wheat or barley, causes disintegration. As no other malt extract was used it is evident that this ferment has a decided soluble action upon the endosperm-cellulose of *Bromus mollis*, where the cell walls are considerably thickened, and also on the cell walls of other grass seeds. It is also interesting to note here that heating the

*Bot. Zeit. 20: 248, 249. pl. 9. 1862.

enzymes totally destroys the activity as a cellulose dissolving agent, and that it does not pre-exist in the resting seeds, but it is a product of germination.*

The reserve foods, as indicated, consist of two general classes, the carbo-hydrates occuring under three forms: sugar, starch and cellulose, and the albuminoids occurring in the form of albumoses and the vegetable globulins. Of course these are very concentrated. In the aleurone cells the albuminoids have received special names in different seeds.

The outer row of cells of the embryo make up what is known as the cylinder epithelium, or referred to as the epithelium. (Fig. 51 A.) The embryo contains very little starch or none. Now the dissolved material of endosperm is transferred through the absorptive epithelium by diffusion and transferred to the growing embryo within a few hours after the moistened corn is put under favorable conditions for germination. The protoplasm of the epithelial cells becomes coarser in structure, and the granules increase in size. The contents of the cells and nucleus are less distinct; they reach their maximum change in from 24 to 36 hours. At this stage the epithelium ceases to produce its secretory enzymes. The protoplasm loses its large granules and contains small refractive granules. The cell contents become hyaline. The contents of the endosperm become gradually absorbed, the cells having become greatly elongated. The first action of the endosperm is a dissolution of the cellulose and the appearance of transitory starch in the scutellum or cellulose, and therefore acts first in supplying the growing embryo with food. "In the first place the cellwall swells up slightly, and its stratification becomes much more apparent, owing to a partial separation of its constituent lamellae. These are gradually disintegrated, but the middle lamella appears to offer a somewhat greater amount of resistance than the other. Ultimately the whole of the cellwall is broken down into very minute spindle-shaped fragments, with their long dimensions arranged tangential to the original cell-wall. Owing to this arrangement, these minute fragments, when viewed with low powers, gives the appearance of ghost-like cellwalls for some time after the wall has really ceased to be continuous. Ultimately, as the action continues, the residual fragments also disappear, and there is no visible sign of sepa-

*These writers, Research of the germination, etc. Jour. Chem. Soc. 57: 465., give an account of obtaining these enzymes.

ration between the contents of contiguous cells. In the case of starch grains, minute pitted furrows occur. These increase in number until the grains become very irregular, showing large radial clefts. It may be stated in this connection that the embryo acts like a parasite. It is well known that the embryo can very readily be removed from the endosperm. Sachs* points out that the embryos of normal plants are of a parasitic nature, and it has been shown by several investigators that it is possible to excise the embryo of various seeds and germinate plants. Thus Van Tieghem†, who discussed the dependence of various parts of the embryo and the amount of dependence of the embryo upon its endosperm. In this work the writer experimented with both albuminous and ex-albuminous seeds. Among the former corn was used. Van Tieghem reached the important conclusion that the young plant can develop without the aid of endosperm, up to a certain stage. That the nutritive matter of the endosperm can be replaced, up to a certain point, by a paste formed of its own substance, or by the paste containing the predominating substance of albumen. Further experiments were made by Blociszweski,‡ who demonstrated that the embryo seeds separated, wholly or in part, from their endosperm or cotyledons, could grow without the aid of the stored-up material of the endosperm or cotyledons, and that assimilation begins, providing that the plumule has the necessary amount of light.

Now, Brown and Morris succeeded in growing the embryo of barley seeds, when grafted upon the endosperm of other barley seeds; that these embryos grew as well as others dependent on its own endosperm. The foreign endosperm underwent all the usual changes. They succeeded likewise in obtaining a growth of barley germs upon wheat. They concluded that the starch-containing portion of the endosperm is simply a storehouse of dead reserve material, and that it is not vital in any sense of the word.

Time required for germination.—We may next inquire what time is required for germination. Nobbe,§ in his admirable work on seeds, states that seeds of cereals and clovers in general require 10 days. *Melilotus alba*, Avena, beets, Cucurbitaceæ, grasses (excepting Phleum, which germinates in ten

*Physiology of Plants. 378.
†Ann. des Sci. Nat. V. 17: 205.
‡Landw. Jahrb. 5: 14. Abst. Jahr. d. Agr. Chem. 1875: 232.
§Handbuch der Samenkunde. 511.

days), need fourteen days, and Abietineæ, twenty-one days. Gilbert H. Hicks* gives the germinative energy for cereals, clovers, peas, vetches, flat peas, flax, dodder, poppy, Brassica, Lepidium, radish, spurry and chicory at three days. For ordinary field conditions this is somewhat too short a period. In laboratory and greenhouse our tests show that corn requires five or six days as an average.

The time required for germination varies greatly. This depends largely upon external conditions. Sachs has given us the following temperature required for germination:

	OPTIMUM.	MAXIMUM.	MINIMUM.
Zea mays (corn)	33c	46c	9.5
Triticum vulgare (wheat)	29	42	5
Hordeum vulgare (barley)	29	38	5

Haberlandt gives as the maximum temperature of germination of cereals the following: Wheat, 31-37 C; rye, 31-37 C; barley, 31-33 C; oats, 31-37 C; corn, 44-50 C; millet, 44-50 C.

He has determined the minimum temperature and rapidity of germination as follows: Time of counting when caulicle appeared:

	4.75 C.	10.5 C.	15.6 C.	18.5 C.
Winter wheat	6	3	2	1.75
Winter rye	4	2.5	1	1
Barley	6	3	2	1.75
Corn		11.25	3.25	3
English rye grass	10	5.5	3.75	3
Timothy		6.5	3.25	3

O. Burchard has made the following determination of grass seed and temperature:

	CONSTANT TEMPERATURE, 68° F.				CONSTANT TEMPERATURE, 86° F.				
Germination after days	5	7	14	28	5	7	14	21	28
Poa pratensis, per cent.	5.06	13.89	24.39	25.73	6.45	10.11	12.28	13.61	12.61
Poa trivialis, per cent.	16.17	39.67	69.33	71.83	19.83	31.83	33.25	39.17	40.0
Poa nemoralis, per cent.	8.75	18.58	26.83	27.12	7.0	13.5	17.43	17.59	17.59
Poa annua, per ct.	54.9	76.33	71.83	75.17	56.83	68.0	72.83	73.67	73.67
Poa compressa, per cent	0.0	0.17	0.5	0.67	0.0	1.67	3.33	3.33	3.33
Agrostis stolonifera, per cent.	59.5	63.92	64.59	64.75	78.17	83.33	84.59	85.0	85.0
Alopecurus pratensis, per cent	9.75	30.67	64.5	71.92	8.08	30.84	59.75	64.84	65.15

*Year Book. U. S. Dept. of Agrl. 1894: 399.

	CHANGEABLE TEMPERATURE.			
Poa trivialis, per cent	35.33	62.0	73.67	75.33
Poa nemoralis, per cent	18.0	43.5	56.17	57.67
Poa annua, per cent	72 17	83.33	84 67	84.67
Poa compressa, per cent.	0.0	18.17	53.17	54.5
Poa pratensis, per cent.	11 72	21.11	45.28	49 84
Agrostis stolonifera, per cent.	90.34	96.0	96 43	96.42
Alopecurus pratensis, per cent	14 5	46 67	72.34	74.43

Vitality.—When the necessary conditions are present—a favorable temperature and moisture—the process begins. The first step is absorption of moisture. When this has proceeded far enough, and with the required amount of heat, the radicle breaks through the coleorhiza or root sheath. The first leaf surrounds the other leaves in the form of a tube, and pushes through the ground; later it opens out. In some cases a single strong primary root appears, but in others a number may even break through the root sheath. The scutellum remains within the pericarp The young plant is nourished by the material stored away in the endosperm. It is transferred to the embryo by a row of palisade cells that occur on the outside of the scutellum. The walls are delicate, and during their activity are made up of granular cytoplasm. During the process of germination, the protoplasm does not only become active, but is changed in its structure, as will presently be shown. Now, as a further evidence of germination, it is well known that during the process, evolution of heat takes place. This is due to oxidation. This process has also been called respiration. The carbohydrates are consumed and CO_2 is given off. This may easily be shown by germinating corn or rye or oats in a close atmosphere in a vessel which does not permit the produced gas to escape. This gas may afterwards be collected in the well known respiration apparatus of Sachs'. The activity of respiration, that is, the carbon dioxide, given off by a given plant, will vary according to the state of development of the seed. At first little will be given off, and as the process of germination increases, more will be given off; as the material is consumed more and more, the process diminishes and the activity of respiration ceases.

Fig. 56 A. Germination of wheat. (King)

It has also been shown that plants, during germination, do not lose any nitrogenous

substances, nor do they form nitrogen gas. T. H. Schloesing, Jr.,* who experimented with lupines, concludes that the seeds of plants do not lose any of their nitrogenous substance in the form of gas during germination. Soon after germination is under way the primary root produces lateral rootlets; these as well as the main root form root hairs that serve to bring nourishing material from the soil as well as to anchor the plant. The following table by Nobbe is interesting as showing the germination of grasses compared with other plants.

	Maximum.	Minimum.	Mean.
Agrostis stolonifera	55	1	28
Pinus strobus	15	10	13
Allium cepa	93	47	63
Alopecurus pratensis	28	1	9
Arrhenatherum avenaceum	84	26	55
Avena sativa	98	97	98
Phleum pratense	99	62	86
Zea mays	98	18	87
Brassica oleracea	97	1	47
Daucus carota	87	10	58
Linum usitatissimum	99	82	89
Medicago sativa	95	42	86
Trifolium pratense	98	39	87
Lactuca sativa	63	14	37
Meadow grasses	49.8	6.4	27.4
Cereals	95	45	81.5
Crucifers	98	52.5	87
Cucurbits	91	39	74

Temperature and germination.—It is a well known fact that temperature is an important factor in the germination of seeds. Nobbe †has given us an instructive table, from which the following is taken:

SEED.	16° C. 60.5° F.		25° C. 77° F.		31° C. 88° F.		37.5° C. 100° F.		44° C. 111° F.	
	Seeds ger.	Hours.	Seeds ger.	Hours.	Seeds ger.	Hours.	Seeds ger.	Hours.	Seeds ger.	Hours.
Barley	100	92	92	72	24	144	......	......	......	......
Cabbage, early small	100	56	100	32	100	48	......	......	......	......
Red clover	100	32	100	24	100	24	100	24	......	......
Corn	80	44	68	56	100	48	100	48	12	80
Flax	100	32	100	23	100	47	......	......	......	......
Oats	100	80	100	48	100	80	100	48	36	96
Timothy	76	168	100	44	88	148	......	......	......	......
Wheat	100	56	100	32	100	48	......	......		......

*Comt. rend. 120: 1278. Abst. Cent. Agrikulturch. 25: 737.

†Handbuch der Samenkunde. 226. Landw. Versuchs. Stat. 117: 74. 1874.

The minimum degree of temperature for corn is 49.9 F., maximum 134.8 F., optimum 91.4 F. To this table may be appended the results obtained for a few cereals in our laboratory, greenhouse (were germinated in sand) and field. The temperature of the laboratory was not kept. The seeds of the laboratory were germinated in porous clay trays.*

LABORATORY AND GREENHOUSE TEST.

VARIETY.	GREENHOUSE.						LABORATORY.
	Temperature, 7 A. M.	Temperature, 1 P. M.	Temperature, 7 P. M.	Humidity, Minimum.	Humidity, Maximum.	Per ct. of germ.	Per ct. of germ.
Yellow dent	89 89	67.13	86.21	37 86	58.26	16	88½
Dent	88.89	60	89 88	35	88.56	73	78½
White dent	87 6	75.38	90 26	33.56	80.25	100	85
Dent	86.7	73	58.9	30.1	81 1	12	66½
Dent	85.77	69.92	77.15	48.77	86 96	75	89
Mills Co. white dent	82	62 5	88	38.3	81.1	100	100
Striped corn	85 88	74 5	89.83	42	75.17	98	100
Early Minnesota Sweet	88	63.8	88	38.9	81.1	98	76
Pop corn	88.59	69.39	81.86	38	83 29	100	100
Feeder's Favorite	80.89	60	88.38	35	88.54	88	76
No. 5	78	66½	69 2	58 2	98	100	90
No. 6	70.8	66½	69 2	62 2	98	100	100
University No. 13	70.8	66½	69.2	58 2	92	100	100
Bloody Butcher	70 8	65½	69.2	58.2	98	98	98½
Iowa Silver Mine	70.8	65½	69 2	52 2	98	100	100

According to Sempolowski, the percentage of germination in grasses is as follows:

	Max.	Min.	Ave.
Agrostis stolonifera	59	8	28
Agrostis alba	21	18	19
Aira caespitosa	9	2	6
Aira flexuosa	50	19	5
Alopecurus pratensis	9	1	5
Anthoxanthum odoratum	42	10	23
Arrhenatherum avenaceum	55	25	44
Arrhenatherum flavescens	28	......	14
Bromus mollis	96	46	72
Cynosurus cristatus	55	4	23
Dactylus glomerata	84	10	58
Festuca ovina	68	14	48
Festuca pratensis	75	35	54
Festuca rubra	70	21	39
Holcus lanatus	39	16	27
Lolium italicum	[illegible]	25	62
Lolium perenne	92	57	75
Phalaris arundinacea	12	8	10
Phleum pratense	96	[illegible]	90
Poa pratensis	25	1	9
Poa nemoralis	6	1	[illegible]
Poa trivialis	7	2	7

*A fuller account of these studies is given by Pammel. Proc. Soc. Prom. Agrl. Sci. 1896: 134. Contr. Bot. Dept. Iowa St. Coll. Agrl. and Mechanic Arts. 13.

On the general subject of climate and its influence on the germination of seeds, little that is positive can be said. In some of our own experiments the California seeds germinated better, and the plants were more vigorous than those of Iowa, but it should be taken into consideration that the California wheats are soft and that it is not improbable that the reserve food substances were brought into a state of solution sooner than in the hard wheats. The very striking differences reported by Professor Bailey in corn do not occur in wheat. The cross-bred wheats and other varieties grown in the state of New York and the East, seems to have germinated slower than those from the Mississippi Valley states, especially so when compared with the wheats of Kansas, Iowa and Wisconsin. As stated in a previous paragraph, the California wheats were especially characterized by the high per cent of germination and the vigor of the young plants. It may be stated that the test made with these plants occurred several months later than those made with the other wheats. Yet a second trial gave us nearly the same results.

In the second trial the plants were all grown at the same time. The Early May of Kansas was comparable with the Patati, only somewhat stouter. The Bissell and Andrews were smaller than the Early May. The Turkey Red, Kansas, was smaller than the Bissell. The cross-bred wheats lacked vigor, and were extremely slow in coming up. The Canada Hybrid, in this experiment, came up rather slowly, although finally it grew quite vigorously.

The following table shows the influence that latitude has on the germination of a single variety of wheat tested at Ames.

VARIETY AND SOURCES.	GERMINATION AFTER DAYS, PLANTED 1 INCH DEEP.						
	4	5	6	7	8	9	10
Turkey Red, Atlantic, Iowa (Franklin).....	13	38	42	....	43	....	44
Turkey Red, Manhattan, Kans	6	20	31	33	40	42	43
Turkey Red, Iowa Experiment Station. ...	....	2	4	12	15	22	36
Turkey Red, Des Moines, Ia. (Ia Seed Co.)	5	21	31	36	44	43	44

It may be of interest to briefly compare the germination of the different varieties of wheat from different states grown under the same conditions. This work was carried out several years ago by Pammel and Stewart.

Early May, from Kansas, total percentage of germination, 88. All of the seed practically germinated in eight days; one-

half in four days. Martin Amber, La Crosse, Wis., only seven seeds germinated in four days; 78 per cent in thirty-nine days. Red Clawson, N. Y., two seeds germinated in six days; six seeds in eight days; after the twelve days seventeen had germinated or 38 per cent. Missogen, Cal., none had germinated in the four days; on the fifth day forty-five seeds had germinated; on the sixth day seventy-seven seeds; on the seventh day ninety-six seeds.

The lowest temperature at which maize will germinate according to Sturtevant is 43.7 F., for all the varieties. It is probable that further trial will place the lowest temperature at 42 or below, but the difficulty of keeping an unquestioned record between close limits for a long period is very great. In Experiment 4, Sturtevant succeeded for twenty-nine and one-half days, when repairs to the water service necessitated its conclusion.

An extended series of tests made at the college the past season from seed collected about Ames, and quite a number of seed sent from other sources, show the following instructive results.

GERMINATION OF CORN WHEN KEPT UNDER DIFFERENT CONDITIONS.

VARIETY.	WHERE KEPT.	AGE. '95	AGE. '96	Per cent. Germinated.
Yellow dent	Open crib college barn	2	....	33⅓
Calico dent	Seed of 1895, closed crib	2	....	93⅓
Legal tender	Dry room	2	....	100
Yellow dent	Shock	....	1	66⅔
Calico	Open crib	2	....	60
Calico corn	Loft above a chicken coop	....	1	100
Sweet corn	Seed of 1896, shock	....	1	100
White rice pop	In paper packages	....	1	100
Iowa silver mine	College seed room	....	1	100
Stowell's evergreen	College seed room	....	1	88

This table certainly shows that when the corn is kept properly there is little danger from deterioration. It is impossible to judge the quality of corn by germinating early in the season when the atmosphere is humid and cold. Seeds kept in damp places when brought into the laboratory frequently germinate well. On drying, however, these seeds soon lose their vital-

ity in a few months. In our experiments the seeds were kept in a dry room and kept under the same conditions.

A number of experiment stations have tested the vitality of corn seed and from the results the following is gleaned. Saunders* states that out of eleven tests the highest percentage was 100, the average 76 down to 63. Corn tested, two varieties, maximum 77, minimum 70, average vitality 73.5. A. J. Pieters† states that in Egyptian sweet corn the germination was 76 whereas it should have been 92.5.

A. Burgerstein‡ who conducted some experiments testing the 10 years old seed of cereal arrives at the following conclusions. Barley retains its vitality better than other seeds. Seeds of this cereal 8 to 10 years old are not especially different than that of from 2 to 7 years old. Oats are nearly as good. In the case of wheat 90 to 100 per cent germinated in from 1 to 4 years; in 5 to 7 years, 85 to 87 per cent; 8 to 10 years, 70 to 80 per cent. The number of wheat seeds capable of germinating diminished 20 to 30 per cent in a single decade. In the case of rye the percentage of germination in 5 years dropped to 65 per cent; 7 years, 36 per cent; 9 years, 13 per cent; 10 years, 1 to 2 per cent. Rye had practically lost its germination in ten years.

The results of some experiments made with wheat at the Iowa experiment station§ indicate that some of the cross-bred wheats s on lose their vitality.

Regermination.—It has been a common belief among many farmers, as well as others, that certain seeds were capable of germinating more than once. Mr. C. H. Andric‖ states that he observed the regermination of wheat. This fact has been likewise observed for corn, oats and rye. The question is therefore of general interest; we have in this connection summarized the work of several experimenters as well as some original work done at this station several years ago. Professor Goff¶ has done some rather interesting work in connection with corn. He sprouted the seeds in apparatus and then removed to a warm dry place where they were allowed to

*Canada Experimental Farms. Appendix to the Report of the Minister of Agrl. 1892: 40-42.

†Year Book U. S. Depart. Agrl. 1895: 176.

‡Naturw. Rundschau. 1896: 23. Verhandl. geo. bot. Gesells. Wien. 45: 414. Abst. Biedermann's Cent. Bl. Agrikulturch. 25: 637.

§Pammel. Proc. Soc. Prom. Agrl. Sci. 1898: 194.

‖Wallace's Farmer and Dairyman. 1897: 150.

¶Ann. Rep. of the Board of Control, N. Y. Exp. Sta. 2: 65. 1883.

remain seven days and then germinated. The following table shows the result of his work:

WAUSHAKUM FLINT CORN.

1st Test.	2d Test.	3d Test.	4th Test.	5th Test.	6th Test.
100.	97.	97.	65.	20.	0.

Total number of days dried, 47.

WHITE RICE POPCORN

1st Germ.	2d Germ.	3d Germ.	4th Germ.
100.	96.	29.	44.

Total number of days drying, 28.

BLOUNT'S PROLIFIC DENT.

1st Germ.	2d Germ.	3d Germ.	4th Germ.	5th Germ.	6th Germ.
96.	83.	14.	0.	12.	0.

Total number of days dried, 28.

Beal, of the Michigan Agricultural college,* did some work along the same line with wheat. Later Ten Eyck,† made some experiments at Madison, Wis., from which it appears that corn, "Pride of the North," first germinated 100 per cent., 500 seeds being used in this test. Second, 285 seeds tested 97.54 per cent. Third test 213, 23 per cent. Fourth test 43 seeds used, 11.68 per cent. Fifth test, 5 seeds, no germination. Total number of days dried, 21. In the second trial the same variety of corn was used. First germination, 500 seeds used, per cent of germination, 99.82; second germination, 276 seeds used, per cent of germination, 77.90; third test, 196 seeds used, per cent of germination, 66 33; fourth germination, 77 seeds used, per cent of germination, 64.94; fifth test, 23 seeds used, per cent of germination, 52.17; sixth germination, 12 seeds used, per cent of germination, 16.67; seventh test, 2 seeds used, per cent of germination, 0. To al number of days dried, 42.

One of us and Mr. F. C. Stewart, some years ago, made regermination tests, but the work was not entirely completed, owing

*Rep. Mich. St. Board Agrl. 1881-1882: 123.
†Agrl. Sci. 6: 454. 1892.

to an interruption in the plan of the experiments, but the results made were interesting and instructive. The results of the work indicated that seeds which were soaked for a considerable period of time and then allowed to dry, failed to show as good germinating plants as those not soaked. The per cent of germination being in some cases lower and on the whole the germination proceeding more rapidly when the seeds had been moistened. The germinated plants from seeds moistened for a considerable period were easily subject to the attacks of saprophytic fungi, and hence made a very feeble growth.

Rambousek* states that experiments with rye, wheat and barley have shown that such seeds in which the radicle only is injured may continue to germinate, and that in this respect wheat and rye are much more resistant than barley.

THE PURITY AND VITALITY OF GRASS SEED.

CARLETON R. BALL.

In the following pages have been brought together most of the available facts pertaining to this subject which seem important in determining the status of our grass seeds with reference to their purity and vitality. Reference has been made to only such works as gave the results of a considerable number of tests and the subject is further confined to our own country. For four of our common species the results obtained from miscellaneous sources have been summarized by the author under the heading "various other tests," and all the data are presented in tabular form for better comparison.

A study of the tables will show beyond doubt that the quality of commercial grass seed has improved considerably in the last fifteen years. It will also show as conclusively that further improvement is not only necessary in the interest of good pastures and clean farms, but is also easily possible. Tables Nos. V, VI and VII give both purity and vitality of a large number of species of grasses.

PURITY.

Since the '60's, when Nobbe made his classic disclosures of the deplorable state of affairs which then existed in Europe,

*Prager. landw. Wochenblatt. 1895: 393. Centr. Agrikulturch. 24: 393.

the fact that the commercial seed of grasses and forage plants contain relatively large amounts of impurities has been quite generally appreciated. It is true that the quality has improved considerably since that time. This is due largely to the establishment and operation of numerous seed-control stations and the prosecution of similar work by many of our American experiment stations. Good descriptions and illustrations of grasses have become more available for popular use and thus a discriminative knowledge of them more widely diffused.

A discussion of the impurities of grass seeds may be taken up under two heads as follows:

a. Intentional adulteration.

b. Na ural or accidental impurities.

Intentional adulteration.—The substances principally used to adulterate the seeds of grasses are fine sand and the seeds of cheaper and often very inferior grasses. Neither of these can be detected except by a careful examination. In fact it is almost impossible for the average consumer to detect the presence of a foreign grass seed in his package because the seeds of some species resemble each other so closely as to render it difficult for the specialist to distinguish them. Rolfs reports* finding sand in some quantity in the seeds of fiorin or bent grass (*Agrostis alba*) and sweet vernal grass (*Anthoxanthum odoratum*). McCarthy† states that sand and crushed quartz rock have been detected in samples of timothy.

The seed of English or perennial rye or ray grass (*Lolium perenne*) is commonly used to adulterate the seeds of other grasses, partly because it is very cheap and partly because it resembles them closely. It is frequently found in the seeds of such grasses as tall fescue and meadow fescue (*Festuca elatior* and *F. elatior pratensis*), Italian ray grass (*Lolium italicum*) a dearer and better grass, and in orchard grass. Rolfs found 41 per cent of it in a pound of the Italian ray grass and 11 per cent in water fescue. The amount in orchard grass is discussed under that species. Sheep's fescue is sometimes used in seeds of crested dog's tail and is sometimes sold as red fescue. Seeds of several species of worthless Poas are used with the seeds of rough-stalked meadow grass (*Poa trivialis*) an imported grass. Several other grasses are less frequently used.

*Preliminary report on the examination of some seeds. Bull. Iowa Agr. Exp. Station 13: 75-86.

†Seed testing: Its uses and methods. Bull. N. C. Agr. Exp. Station. 108: 349-415. 1894. See 382-391. (Also Bull. 73: 73-78: 1889).

Natural or accidental impurities.—Under this head must be placed the varying amounts of dirt, sand, sticks, dead seed and chaff resulting from improper cleaning, and also the seeds of weeds and weedy grasses which grow naturally, or through introduction, with the valuable grasses. Of the first series there will always be a small amount in the best cleaned seed. The amount of weed seeds can, however, be easily reduced to practically nothing by pulling up the weeds before the grass seed is harvested. The desirability of any sample of seed is not always fairly indicated by the percentage of weed seed it contains, for it is readily seen that a small per cent of a very bad weed would be more dangerous than a much larger per cent of a comparatively harmless weed.

One of the most common weeds whose seeds are found in grass seed is plantain (*Plantago major*). The lance-leaved plantain or rib grass (*P. lanceolata*) is being rapidly scattered over this country by means of imported grass seed. Other common weeds are sheep sorrel (*Rumex acetosella*), dock (*Rumex crispus* et al), shepherd's purse (*Capsella bursa-pastoris*), May weed (*Anthemis cotula*), pigweed (*Amarantus* sp.), lamb's quarter (*Chenopodium album*), mallow (*Malva sylvestris*), buttercup (*Ranunculus* sp.), and occasionally Canada thistle (*Cnicus arvensis*), and ox-eye daisy (*Chrysanthemum leucanthemum*).

Among the weedy grasses whose seeds are troublesome may be mentioned the pigeon grasses or foxtails (*Chaetochloa viridis* and *C. glauca*). These are especially common in clover seed, hence are apt to get into grass fields. Some European seeds contain the seeds of blue pearl grass (*Molinia caerulea*) and darnel (*Lolium temulentum*), two dangerous grasses. Chess or cheat (*Bromus secalinus*), wild oats (*Avena fatua*), and sand bur (*Cenchrus tribuloides*) are also met with. Seeds of many other less harmful or of valuable species are found mixed with what should be pure seed of one species. Gilbert H. Hicks* says: "Very few kinds of grass are raised for seed purposes alone; hence most grass seed is obtained from meadows or places where different species are found growing together."

The following tables set forth some comparative facts concerning the purity of the seeds of four of our common grasses. The first column shows the number of samples of which tests were made. The last three columns show the minimum, average and maximum percentages of pure seed in each series of

*Pure seed investigations. Yearb. U. S. Depart. Agril. 1894: 389-408.

samples. I have quoted from a very good table of purities compiled by C. L. Parsons,* and have also given the tabulated results of various tests collated by myself. The standards of purity established by the U. S. Department of Agriculture in 1896 and those of McCarthy† in 1894 are also given.

Poa pratensis. Blue grass.—The seed of blue grass is not often purposely adulterated and is usually quite pure seed. It contains relatively little of weed seeds, and the impurities consist of small amounts of sand, dirt and sticks, with often a large per cent of chaff.

TABLE NO. I.

PURITY OF BLUE GRASS SEED.	Number.	Minimum.	Average.	Maximum.
Various tests	8	94.	97.7	100.
Parsons, summary of American tests	5	92.	96.7	99.
U. S Department of Agriculture, standard	....	....	90.	......
McCarthy, standard	....	....	84.8	......

Agrostis vulgaris. Red top.—There is little adulteration of red top seed. Rolfs reports one sample containing much quartz sand. When it is allowed to ripen until the seed shells out a large amount of empty chaff will be found in the packets. It usually contains dirt and the seeds of such low-ground plants as dock, plantain, buttercup, sedges and timothy.

TABLE NO. II.

PURITY OF RED TOP SEED.	Number.	Minimum.	Average.	Maximum.
Parsons, summary of American tests	6	14.	48.3	100.
Various tests	7	16.	63.1	100.
Mc arthy, standard	....	....	97.4	......

Dactylis glomerata. Orchard grass.—The condition of orchard grass seed was thoroughly investigated at the Connecticut Experiment Station in 1892.‡ Their results were summarized as follows:

*A summary of American seed tests. Agri. Sci. 7: 541-545.
†Yearb. U. S. Dept. Agri. 1896: 623-624.
Conn. Agr. Exp. Station. Ann. Report 1892: 152-154.

"*First.*—Of the seventeen samples of orchard grass purchased in New York, Boston, and at various places in Connecticut, one sample contained as much as 98.8 per cent of pure seed, the remainder being chaff. Another contained no orchard grass seed whatever, and consisted mainly of *Lolium perenne*, or perennial rye-grass. Excluding this sample the other sixteen samples contained on the average 77.4 per cent of pure seed.

"*Second.*—Seven out of sixteen samples contained notable quantities, from 8.3 to 35.5 per cent, of seed of perennial rye-grass, *Lolium perenne*, which is less valuable and sells at a lower price. 'Tested' orchard grass seed is quoted at 11 cents per pound and 'tested' perennial rye grass at 4.5 cents. A single sample contained 14.1 per cent of a species of *Bromus*, probably *B. secalinus*, or chess." McCarthy says uncleaned seed often contains one-fifth of its weight in chaff, dirt, and various weed seeds. The most common weeds are dog fennel or May weed, ox-eye daisy, sheep sorrel, and species of knotweed or heartsease (*Polygonum*).

TABLE NO. III.

PURITY OF ORCHARD GRASS SEED.	Number.	Minimum.	Average.	Maximum.
Connecticut Experiment Station, 1892	17	......	72.85	98.8
Parsons, summary of American tests	10	39.	87.2	100.
Various other tests	7	84.75	95.25	100.
McCarthy, standard, 1894	...	......	73.9	......

Phleum pratense. Timothy.—Timothy seed is usually quite clean. It is sometimes adulterated with sand and quartz and generally contains small quantities of dirt, sticks, and chaff, and the seeds of various weeds, clover, and some grasses. Among the common weed seeds are those of plantain, dock, buttercup, May weed, shepherd's purse, pigweed, and mallow. Of the grass seeds, red top, fowl meadow (*Poa serotina*), and the pigeon grasses or foxtails, are most commonly found. Professor Chester* found seed of Canada thistle in one sample.

*Ann. Rep. Delaware Exp. Station. 1889: 37-63. (Also Bull. 5).

TABLE NO. IV.

PURITY OF TIMOTHY SEED.	Number.	Minimum.	Average.	Maximum.
Parsons, summary	16	67.	92.75	100.
Various tests	20	95.15	98.5	100.
McCarthy, standard for choice	....	....	97.6	......
U. S. Department of Agriculture, standard	....	....	98.	......

Cereals.—An article on this subject would hardly be complete without something in regard to the purity of the seed grain of this country. As a rule they have a very high standard of purity; 99 per cent pure is the government standard, and that established by McCarthy was over 97.5 per cent. The seeds of a few weeds are usually to be found in wheat seed and to a lesser extent in oats. The most frequent of these are chess or cheat (*Bromus secalinus*), corn cockle (*Lychnis githago*), sheep sorrel (*Rumex acetosella*), pigeon grass, foxtail (*Chaetochloa*), rib grass (*Plantago lanceolata*) and garlic (*Allium vineale*). W. S. Devol,* who examined several samples of wheat seed, states that the seed of chess may be present in wheat at the rate of 9,000 per bushel and still amount to only about one-tenth of 1 per cent, and that the seed of corn cockle at the rate of 1,888 seeds per bushel would make only six-hundredths of 1 per cent of the total. Let us have a pure seed league with the motto, "An ounce of prevention is worth a pound of cure."

VITALITY.

It is a well known fact that the seeds of grasses have a comparatively low vitality. It is also a fact, though perhaps not so generally known, that the vitality of the average sample of commercial grass seed, as determined in germination tests, is much below what may be taken as an average standard. In fact, the average vitality of commercial grass seed is considerably lower in proportion to this reasonable standard for grass seeds than are the average vitalities of most other commercial seeds in proportion to the reasonable standards determined for them.

There are several reasons which, taken together, will largely account for this state of affairs. In the first place, the seeds

*Fourth Ann. Report Ohio Agri. Exp. Station. 1885: 183-186.

of grasses have been a commercial article for a much shorter period of time than have the seeds of most of our field and garden crops. Grasses were long regarded as one of nature's gifts, like air and water, and as little effort was made to improve their quantity or quality; little attention was paid to their seeds until recent years when various causes have combined to place hay and pasturage among the most important of our farm products. At the present time only imperfect devices exist for gathering and cleaning the seed, and little is known as to the best methods for increasing and retaining the vitality. In order to secure the greatest quantity at the least expense the seeds of many species are gathered while still green, and in this way the vitality is doubtless impaired. The drying of such green seeds is often imperfectly done and many of the seeds become mouldy.

The demand for the seeds of any but the most common kinds is so very limited and irregular that they may be held over from year to year in the unsold stock of the seedsman until their vitality is almost or completely exhausted.

In many of the grasses, as the blue grasses (Poa species), fescues (Festuca species), ray grasses (Lolium species), orchard grass (*Dactylis glomerata*), and others, the seed as gathered consists of not only the grain or caryopsis itself but also of the flowering glume or chaff which surrounds the seed more or less closely. This fact often makes it very difficult to say whether what appears to be a seed actually contains a seed or whether it is only an empty chaff. This can be determined only by a careful examination. Where this empty chaff made up a large per cent of the total it is evident that the vitality of the supposed seed would be very low.

Table No. V gives the average percentages of purity and vitality possessed by choice grass seeds. The figures were obtained from an extensive series of microscopic examinations and germination tests and were compiled by Prof. Gerald McCarthy from his own work* at the North Carolina Experiment Station, from the reports of many other American stations and four of the leading European seed stations, and from data furnished by many American and foreign seedsmen. The last three columns give the maximum, minimum, and optimum temperatures for germinating these seeds.

*Bull. N. C. Agr. Exp. Station. 108: 383-384. 1894.

TABLE No. V SHOWING VIABILITY AND PURITY OF GOOD COMMERCIAL SEEDS, AND TEMPERATURE AT WHICH THEY GERMINATE.

KIND OF SEED.	Viability per cent.	Purity per cent.	TEMPERATURE. Maximum ° F.	Minimum ° F.	Optimum ° F.
Grasses and Cereals:					
Agrostis stolonifera (florin)	82.	71.1	95	60	75
Agrostis vulgaris (red top)	72.	97.4	95	60	75
Alopecurus pratensis (meadow foxtail)	42.	83.5	95	60	75
Anthoxanthum odoratum (sweet vernal)	30.	85.7	95	60	75
Anthoxanthum puelli (annual sweet vernal)	26.	83.7	95	60	75
Arrhenatherum avenaceum (tall oat grass)	69.	68.1	95	60	75
Avena sativa (common oats)	95.	97.5	90	55	70
Avena flavescens (yellow oat grass)	37.	42.5	95	60	75
Bromus mollis (soft chess)	46.	64 4	90	55	70
Bromus inermis (Hungarian brome)	81.	76.3	90	55	70
Bromus pratensis (meadow brome)	61.	77.4	90	55	70
Bromus schraderi (rescue grass)	70.	95.	90	55	70
Cynodon dactylon (Bermuda grass)	52.	98.5	95	65	80
Cynosurus cristatus (crested dog's tail)	62.	89.1	95	60	75
Dactylis glomerata (orchard grass)	81.	73.9	95	60	75
Festuca duriuscula (hard fescue)	67.	86.7	95	60	75
Festuca elatior (Randall grass)	83.	85.4	95	60	75
Festuca tenuifolia	60.	71.4	95	60	75
Festuca ovina (sheep's fescue)	71.	80.3	95	60	75
Festuca pratense (meadow fescue)	81.	86.9	95	60	75
Festuca rubra (red fescue)	48.	73.1	95	60	75
Holcus lanatus (velvet grass)	39.	68.2	95	60	75
Hordeum vulgare (cultivated barley)	82.	97.9	95	50	65
Lolium italicum (Italian rye grass)	73.	93.	95	50	75
Lolium perenne (English rye grass)	76.	94.3	95	50	75
Oryza sativa (cultivated rice)	85.	97.1	95	65	80
Panicum germanicum (golden millet)	88.	97.5	95	65	80
Panicum milaceum (millet)	82.	98.	95	65	80
Panicum sanguinale (crab grass)	85.	97.5	95	65	80
Panicum spicata (pearl millet)	82.	98.	95	65	80
Phleum pratense (timothy)	89.	97.6	95	60	75
Poa arachnifera (Texas blue grass)	60.	88.5	95	60	75
Poa compressa (June grass)	70.	80.8	95	60	75
Poa nemoralis (wood grass)	60.	78.9	95	60	75
Poa pratensis (Kentuck blue grass)	60.	84.8	95	60	75
Poa serotina (fowl meadow grass)	75.	83.5	95	60	75
Poa trivialis (rough-stalked meadow grass)	55.	85.	95	60	75
Secale cereale (cultivated rye)	91.	99.	90	55	75
Chaetochloa Italica (Italian millet)	87.	97.5	95	60	75
Sorghum halapense (Johnson grass)	75.	95.	99	65	80
Sorghum nigrum (sugar cane)	75.	97 5	99	65	80
Sorghum saccharatum (broom corn)	75.	97.5	95	60	75
Triticum vulgare (cultivated wheat)	95.	98.2	95	55	75
Zea mays (Indian corn)	95.	98.5	100	65	85

Table No. VI shows the minimum, average and maximum percentages of vitality and impurity for a large number of grasses. The column headed "Days required" shows the number of days required for all vital seed to germinate. "No." indicates the number of tests from which the figures given were obtained. These figures were compiled by Charles Lathrop Parsons* and include most of the tests made up to January, 1891. By comparing this table with table No. V, some interesting facts are brought out. It will be noted that the vitalities are much lower than the standard of table No. V. For example, timothy is about 9 per cent lower, orchard grass 21 per cent, red top 28 per cent, and Kentucky blue grass over 50 per cent lower. These results are based on a large number of tests in each case, as may be seen by referring to the first column.

Table No. VII was condensed from the results of tests published by Prof. F. L. Harvey.† The seeds were germinated in cloth pockets in a galvanized tray containing water in the bottom. In noting these vitalities the reader must bear in mind that the tests were continued for only fourteen days, and that most grasses require a longer period for complete germination. This accounts for the large number of sound seeds remaining at the end of the test. Of course, not all of them would have germinated if the test had been continued, but it is probable that part of them would have done so.

*A Summary of American Seed Tests. Agrl. Science. 7: 541-545.

†Germination Experiments. Maine Agrl. Exp. Station, Ann. Report. 1888: 136-137. (See pp. 143-147.)

TABLE NO. VI.

GRASSES.	VITALITY.				IMPURITIES.				DAYS REQUIRED.			
	No.	Min.	Aver.	Max.	No.	Min.	Aver.	Max.	No.	Min.	Aver.	Max.
Aira flexuosa (wood hair grass)	1	1	1	1	....	....	....	......	1	6	6	6
Agrostis canina (Rhode Island bent grass)	3	47	60	81	2	3	40	77	3	10	11	13
Agrostis stolonifera (creeping bent grass)	2	58	59.5	67	1	17.7	17.7	17.7	1	10	12	12
Agrostis vulgaris (red top or bent grass)	30	4	34.2	98	6	0	51.7	98	5	9	12	15
Ammophila arundinacea (beach grass)	1	2	2	2	......	....	....	......	1	14	14	14
Alopecurus agrostis (slender foxtail)	1	58	58	58	1	2	2	2	1	9	9	9
Alopecurus pratensis (meadow foxtail)	5	2	15	28	1	6.2	6.2	1.2	....	10	12	20
Anthoxanthum odoratum (sweet vernal)	8	5	23.9	80	2	.55	1.80	2.7	3	11	12	13
Anthoxanthum puelii (annual sweet vernal)	1	26	26	26	1	6.7	6.7	6.7	....	......	....	....
Arrhenatherum avenaceum (tall meadow oat grass)	7	2	42.7	98	2	2.65	7.38	11.1	4	8	14	23
Avena flavescens (yellow oat grass)	5	2	24	60	1	6.6	6.6	6.6	......	......	....	....
Bromus mollis (soft chess grass)	2	3	21	40	....	....	....	......	1	6	6	6
Bromus pratensis (meadow brome grass)	1	0	0	0	....	....	....	......	....	....	....	....
Bromus unioloides (brome grass)	3	0	9	18	1	4.77	4.77	4.77	....	....	....	....
Cynodon dactylon (Bermuda grass)	1	66	66	66	1	19	19	19	......	......	....	....
Cynosurus cristatus (crested dog's tail)	5	9	43.2	100	2	.25	1.33	2.4	2	12	14	16
Dactylis glomerata (orchard grass)	18	10	65.9	98	10	0	13.8	61	4	12	13	14
Euchlaena luxurians (teosinte)	5	8	56	88	1	.97	.97	.97	3	9	12	15
Festuca elatior (tall fescue)	6	23	47.4	85	....	....	....	...	....	11	12.5	14
Festuca duriuscula (hard fescue)	7	3	31.1	48	2	1	10.3	19.4	3	12	14	17
Festuca heterophylla (various-leaved fescue)	1	3	3	3	...	......	....	....	1	14	14	14
Festuca ovina (sheep's fescue)	7	0	20.7	54	2	.55	3.07	6.6	3	9	12	15
Festuca pratensis (meadow fescue)	11	6	66.3	98	2	2.4	3.07	3.75	5	10	14	19
Festuca rubra (red fescue)	3	6	48	100	2	1.3	1.65	2	1	19	19	19
Festuca tenuifolia (slender fescue)	3	3	13.3	30	1	3.7	3.7	3.7	1	14	14	14
Glyceria arundinacea (tall meadow grass)	1	14	14	14	1	63.7	63.7	63.7	...	......	....	....
Holcus lanatus (meadow soft grass)	4	0	20	60	3	5	18.7	44.5	2	11	14	17
Lolium italicum (Italian rye grass)	10	4	50.8	98	3	.4	6.1	16.7	4	10	12	17
Lolium perenne (English rye grass)	14	12	63.3	100	4	0	6.8	19.4	4	10	16	21
Panicum miliaceum (millet)	5	64	84	98	.	....	....	....	4	3	4	5
Phleum pratense (timothy or Herd's grass)	51	0	80.1	100	16	0	7.25	28	28	1	7	16
Phalaris arundinacea (reed canary grass)	2	6	80	90	..	....	....	......	1	7	7	7
Poa aquatica (water meadow grass)	3	0	.66	3	2	.25	5.90	11	1	10	20	20
Poa compressa (Canada blue grass)	1	11	11	11	....	....	....	......	1	12	13	13
Poa nemoralis (wood meadow grass)	6	6	10.6	15	1	.10	.10	.10	8	12	15	19
Poa pratensis (Kentucky blue grass)	43	0	6.3	40	5	1	3.3	9	5	11	14	18
Poa serotina (low meadow grass)	6	3	20	50	5	7.56	41.5	80	4	9	10	14
Poa trivialis (rough-stalked meadow grass)	4	3	6.7	13	2	10	12.7	15.4	1	13	13	13
Chaetochloa italica (Hungarian or German millet)	11	5	59.3	88	3	0	.38	48	7	4	9	15
Sorghum halapense (Johnson grass)	5	0	6.6	28	2	3.5	13.2	21	1	4	4	4

TABLE No. VII.

TESTS OF FOURTEEN DAYS DURATION.

KIND OF SEED.	Per cent of impurities by weight.	Sound seeds left.	Percent sprouted.	No. of days required for one-half to sprout.
Agrostis vulgaris, (red top, fancy)	....	20	80	4
Agrostis vulgaris, (red top, fancy)	....	19	64	8
Agrostis vulgaris, (red top, fancy)	84	80	20	....
Agrostis vulgaris, (red top, fancy)	....	75	25	...
Aira flexuosa, (wood hair grass)	....	99	1	....
Alopecurus agrestis, (slender foxtail)	2	43	53	7
Ammophila arenaria, (beach grass)	...	2	97	3
Anthoxanthum odoratum, (sweet vernal)	....	80	14	....
Anthoxanthum odoratum, (sweet vernal)	....	80	19	....
Anthoxanthum odoratum, (sweet vernal)	....	85	15	....
Arrhenatherum avenaceum, (tall meadow oat grass)	....	50	48	....
Arrhenatherum avenaceum, (tall meadow oat grass)	....	98	2	....
Arrhenatherum avenaceum, (tall meadow oat grass)	...	40	60	5
Agrostis canina, (Rhode Island bent)	....	19	81	4
Agrostis canina, (Rhode Island bent)	77	48	52	9
Agrostis canina, (Rhode Island bent)	3	50	47	....
Agrostis stolonifera, (creeping bent)	....	48	52	9
Bromus schraderi, (rescue grass)	....	100	....	....
Bromus pratensis, (meadow brome)	....	100	....	....
Bromus mollis, (soft chess)	....	57	2	....
Cynosurus cristatus, (crested dog's tail)	....	89	11	....
Dactylis glomerata, (orchard grass)	....	60	38	....
Dactylis glomerata, (orchard grass)	....	40	57	9
Dactylis glomerata, (orchard grass)	....	50	50	14
Euchlaena luxurians, (Teosinte)	....	92	8	....
Festuca pratensis, (meadow fescue)	....	87	13	....
Festuca pratensis, (meadow fescue)	....	90	6	....
Festuca pratensis, (meadow fescue)	1	20	73	5
Festuca elatior, (tall fescue)	....	75	25	....
Festuca elatior, (tall fescue)	....	75	25	....
Festuca heterophylla, (various-leaved fescue)	....	97	3	....
Festuca ovina, (sheep's fescue)	....	97	3	....
Festuca tenuifolia, (slender fescue)	....	70	30	....
Festuca duriuscula, (hard fescue)	....	90	3	....
Holcus lanatus, (meadow soft grass)	5	74	22	....
Kaffir corn	....	....	98	2
Lolium italicum, (Italian rye)	....	2	96	3
Lolium italicum, (Italian rye)	...	65	35	....
Lolium perenne, (perennial rye grass)	....	55	45	....
Lolium perenne, (perennial rye grass)	....	57	36	....
Lolium perenne, (perennial rye grass)	....	10	83	4
Panicum miliaceum, (golden millet)	....	2	87	....
Panicum miliaceum, (golden millet)	....	8	91	3
Panicum (Setaria) Germanicum, (Hungarian millet)	....	5	82	2

TABLE No. VII.—CONTINUED.

KIND OF SEED.	Per cent of impurities by weight.	Sound seeds left.	Per cent sprouted.	No. of days required for one-half to sprout.
Panicum (Setaria) Germanicum, (Hungarian millet)	....	50	27	3
Panicum (Setaria) Germanicum, (Hungarian millet)	....	22	68	2
Panicum (Setaria) Germanicum, (Hungarian millet)	....	13	66	2
Phalaris arundinacea, (reed canary grass)	....	94	6	....
Phleum pratense, (timothy)	....	10	88	4
Phleum pratense, (timothy)	....	5	95	5
Phleum pratense, (timothy)	....	10	91	4
Phleum pratense, (timothy)	....	2	96	6
Poa serotina, (fowl meadow grass)	70	88	12	....
Poa serotina, (fowl meadow grass)	50	97	3	....
Poa serotina, (fowl meadow grass)	90	50	50	14
Poa serotina, (fowl meadow grass)	90	68	32	....
Poa pratensis, (Kentucky blue grass)	....	95	5	....
Poa pratensis, (Kentucky blue grass)	....	88	12	....
Poa pratensis, (Kentucky blue grass)	1	83	17	....
Poa nemoralis, (wood meadow grass)	....	85	15	....
Poa nemoralis, (wood meadow grass)	....	86	14	....
Poa aquatica, (water meadow grass)	....	100	....	....
Poa trivialis, (rough-stalked meadow)	10	87	13	....
Poa compressa, (Canada blue grass)	....	89	11	....
Sorghum halapense, (Johnson grass)	....	98	2	....
Sorghum halapense, (Johnson grass)	....	100	....	....

TABLE No. VIII

NAME OF SEED.	Duration of test in days.	Per cent germinated.	Per cent sound unsprouted.	½ germinated in — days.
Red top	15	92	8	3
Kentucky blue grass	18	11	89	3
Red fescue	19	8	92	....
Italian rye grass	17	75	25	5
Meadow soft grass	17	34	66	....
Hard fescue	17	46	54	....
Crested dog's tail	17	9	91	....
Hungarian grass	16	89	6	6
Bermuda grass	23	00	100	....
Meadow fescue	19	84	16	6
Meadow foxtail	19	19	81	....
Water meadow grass	22	00	100	....
English rye grass	21	74	26	11
Sheep's fescue	18	11	89	....
Tall meadow oat grass	23	36	64	....
Wood meadow grass	18	11	89	....

Table No. VIII was condensed from data tabulated by Prof. F. D. Chester. The figures given are the results of duplicate tests in each case. The vitalities average quite high.

In 1877 Professor Beal of Michigan tested the vitality of twenty-two species of forage grasses. These seeds were purchased direct from a seedsman in New York. The seeds, or what appeared to be se ds, were counted out in lots of fifty seeds each, and two lots of each species were germinated between folds of bibulous paper in the greenhouse, at a temperature ranging from 56°–70° F. Two lots more of each species were tested again later and the results of the tests are given below in condensed form:

TABLE No. IX.

FIRST TEST.	Minimum.	Average.	Maximum.
Schrader's bromus	56	62	68
Hungarian grass	62	67	72
Timothy	94	96	98
Nineteen other species	0	8.4	39
SECOND TEST.			
Schroeder's bromus	56	59	62
Hungarian grass	42	45	48
Timothy	30	41	52
Nineteen other species	0	8.1	23

Professor Beal then made tests of some grass seeds which he had gathered on the college farm two and three years before. Besides their age, part of them had been stored in a damp basement. He did not consider them good seed. While testing them he also tested some more from the same lot described above. Both lots were shelled out of the chaff by hand so that there were exactly fifty seeds of each species. The striking results are given below:

*Seed testing. Delaware Agrl. Exp. Station. Ann. Report. 2: 46-57. Also Bull. 5.

†Michigan Board of Agriculture. Ann. Report. 1877: 377-392. See 387-389. Also Beal; Grasses of No. Am. 1: 209-210. (Ed. 2.)

TABLE No. X.

KIND OF SEED.	Eastern seeds.	Old college seeds.
Schrader's bromus	64	96
Sheep's fescue	0	72
Kentucky blue grass	6	28
Rye grass	18	74
Meadow fescue	6	92
Orchard grass	66	82

Blue grass. Poa pratensis.—For convenience of comparison some facts concerning the vitality of four of our common pasture and forage grasses have been set forth separately. The seeds of this very valuable lawn and forage grass possesses the lowest vitality of any of our commonly cultivated grasses. Just why this should be is not so evident. Some facts obtained by G. E. Morrow and T. F. Hunt* are of value in solving this problem. They made vitality tests of eighteen samples of blue grass seed from seventeen different prominent seedsmen and also of one sample of seed gathered on the station grounds. The seed were first tested in the Geneva apparatus for thirty-eight days, and later the tests were repeated in soil in the open air and in the green house, where they continued from March 14th to July 27th

There is such a striking difference in the results obtained from the tests made in the Geneva apparatus and those made in soil that I have tabulated the figures to show this difference, and have added to the column headed "In Geneva apparatus" the results obtained by McCarthy as a standard, those gotten by Parsons, and also those given by fifteen other tests from different sources. The first and fifth columns give the number of samples on which the results are based.

*Ill. Agri. Exp. Station Bull. 15: pp. 478-483. 1891.

TABLE NO. XI.

VITALITY OF BLUE GRASS SEED.	IN GENEVA APPARATUS. Number.	Minimum.	Average.	Maximum.	IN SOIL. Number.	Minimum.	Average.	Maximum.
Seventeen different seedsmen (Morrow & Hunt)	18	0	2	7.	....	.....	....	.....
Seventeen different seedsmen (in open air and shade)	....	....	....	....	18	7.	21.95	35.2
Seventeen different seedsmen (in greenhouse)	....	....	....	....	18	2.5	12.51	22.9
Experiment Station seed	1	0	0	0	....	.....	....	.....
Experiment Station seed (in open air)	....	....	....	....	1	.....	48.3	.....
Experiment Station seed (in greenhouse)	....	....	....	....	1	.....	57.2	.....
Parsons	42	0	6.3	40.	....	.....	....	.....
Various other tests	15	0	7.23	19.	....	.....	....	.....
McCarthy (standard)	....	...	60.	....	....	.....	....	.....
Morrow & Hunt (seed gathered green)	....	....	....	....	3	71.6	72.5	72.8
Morrow & Hunt (seed gathered ripe)	....	....	....	....	1	.....	80.1	.....
U. S. Department of Agriculture (standard)	....	....	45.50	....	...	.....	....	.....

Some seedsmen having claimed that the low vitality of blue grass seed was due to the grass being cut too green and the consequent heating of the seed, tests were made to determine this fact. Three lots of grass were gathered green and dried in as many different ways: one in a cellar, one on the floor in a dry room, and one in a grain sack. After a germinating test lasting about sixty-eight days, they gave vitality percentages of 71.6, 72.5 and 72.8 respectively, while a sample gathered ripe and dried on the floor in a dry room gave 80.1 per cent of viable seed. These figures are given at the bottom of the preceding table. From such results it would seem apparent that for some reason the apparatus for testing seeds does not show the true vitality of blue grass seed as determined by soil tests, and also that careful harvesting and drying of the seed would greatly improve its quality.

Red top. Agrostis alba.—The following table will show the comparative vitality of red top seed in this country, based on a large number of tests.

TABLE NO. XII.

VITALITY OF RED TOP SEED.	Number.	Minimum.	Average.	Maximum.
Morrow & Hunt, from seventeen different seedsmen.	19	4	25	63
Parsons, summary of American tests..............	30	4	34.2	92
Various other tests	10	4	45	92
McCarthy, standard for choice seed..............	....	......	72	.....

It is quite probable that the same conditions that affect blue grass seed affect the seed of red top also, and that if tests were made in soil the general average of vitality might be found to be considerably higher. Better methods of gathering and drying would doubtless work toward the same end.

Orchard grass. Dactylis glomerata.—The most extensive tests of this seed of which I have any knowledge were made at the Connecticut experiment station in 1892. Seventeen samples from different eastern markets were obtained and tested. One was found to contain no seed of orchard grass at all. The results from the remaining sixteen are given in the following table:

TABLE No. XIII.

VITALITY OF ORCHARD GRASS SEED.	Number.	Minimum.	Average.	Maximum.
Connecticut experiment station....................	16	4.5	50	88
Various tests of other stations....................	16	12	53.3	82
Parsons, summary of American tests	18	10	55.9	96
McCarthy, standard for choice seed.......	....	......	81	.....

Timothy. Phleum pratense.—Timothy has been tested for vitality a great many times and approaches more closely to the standard than any other grass. The comparative results are given below:

*Conn. Agr. Exp. Station. Ann. Report. 1892: 153-154.

TABLE No. XIV.

VITALITY OF TIMOTHY SEED.	Number.	Minimum.	Average.	Maximum.
Morrow and Hunt, from sixteen seedsmen	16	42	76	96
Parsons, summary of American tests	51	0	80.1	100
Tests at various stations.	48	30	91.48	100
McCarthy, standard for choice seed	....	......	89	.....
U. S. Department of Agriculture, standard	....	......	85-90	.....

These figures show that the timothy seed is improving in vitality and that the average sample now exceeds the standard once set for choice seed. It is much to be hoped that the next ten years may bring about a similar improvement in the seeds of other species.

Diseases of Germinating Cereals.

Moulds.—The most serious difficulties which corn and other grasses have to contend against in germinating are moulds and bacteria. The following moulds are commonly found: The common blue mould (*Penicillium glaucum*), green mould (*Eurotium* (*Aspergillus*) *glaucus*) and black mould (*Rhizopus nigricans*). Cladosporium, Macrosporium and Sterigmatocystis may occur occasionally, but they are not generally common.

Haberlandt, who made a study of the mouldy rye and its germination, found a gradual decline in its germination as the seed became older.

Logewall, who had observed that rye seed rapidly loses in its power of germination, especially in damp and warm weather, attributes this to micro-organisms. In the case of wheat, however, this did not appear to make any difference. As a result of his rye experiments he determined as follows:

One hundred rye kernels without infection, germination 100 per cent; 100 rye kernels with infection, germination 98 per cent; 100 rye kernels injured without infection, germination 97 per cent; 100 rye kernels injured with infection, germination 91 per cent.

C. Rambousek,† states that moulds of damp seeds destroy the germinative energy to a considerable degree and its distructive influence is most severe on barley.

*Wissenschaftlich praktische Unters auf dem Gebiete des Pflanzenbaues. 1: 66-68, 1875. Harz. Landw. Samen Knude. 1: 294.

†Prager. Landw. Wochenblatt. 1895: 393. Biedermann's Centr. Agrikulturch. 24: 393.

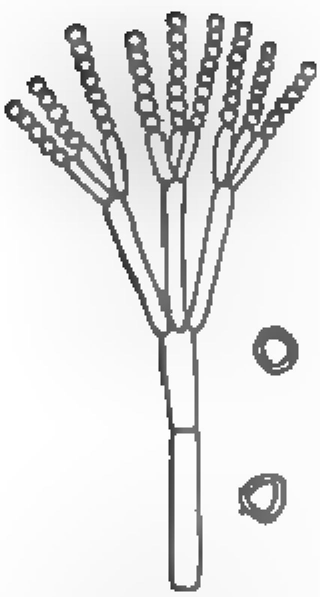

Fig. 61. Common blue mould (*Penicillium glaucum*). Spores at end of branches; spores borne in chains. (Pammel and King)

Penicillium glaucum.—This is one of the most common of all our moulds and is easily recognized by the glaucus green color it produces on the surface. At first a white mycelium spreads over the surface of the seed. It starts usually in the hilar regions. The mycelium, through an enzyme action, undoubtedly, dissolves the starch. Raised masses are formed on the surface. These consist of masses of fungus thread strands. The strands send out lateral branches, from the end of which a whorl of short branches appears, as shown in figure 35. These give rise to one or more whorls. From the ultimate branches a chain of small spores is produced, the last one in the chain being the oldest.

The ascospores have not been found in corn, but occur in poorly lighted places and are produced in the absence of oxygen. The spores produced in chains germinate when the required amount of moisture and heat is present, so that unlimited numbers of generations may proceed from a single spore. These spores also preserve their vitality for a considerable length of time. Brefeld† has shown that they will germinate though kept in a dry place for several years.

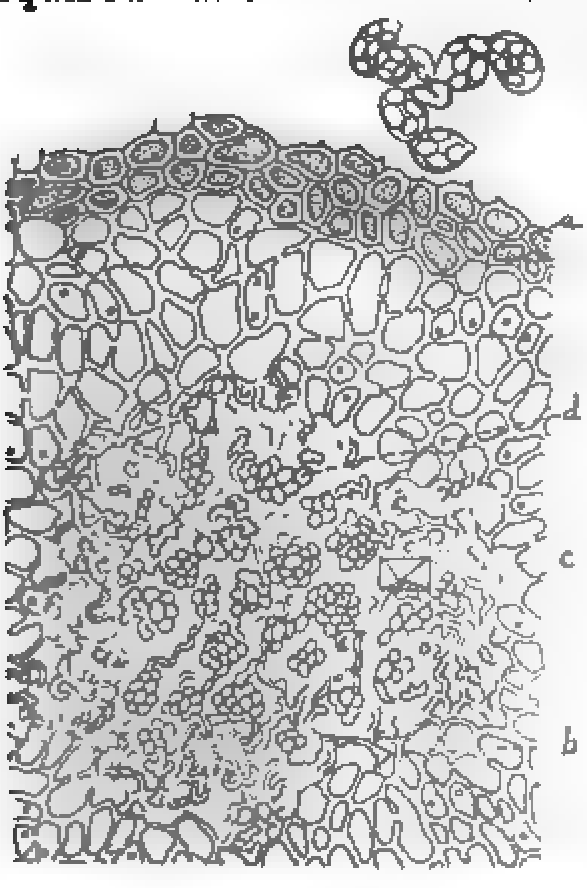

Fig. 62. The sclerotium or resting stage of Penicillium glaucum consisting of a hard compact mass. The asci and ascospores shown above. (Brefeld)

Eurotium (*Aspergillus*) *glaucus* DeBary.—This species is common in stored corn, and will be referred to in connection with a disease of cattle. The mycelium of this fungus spreads over the surface of the corn, in the hilar regions. The bracts surrounding the grain are the special points of attack. From this point the hilar region is attacked. The

†Untersuchung. u. Schimmelpilze. II and IV.

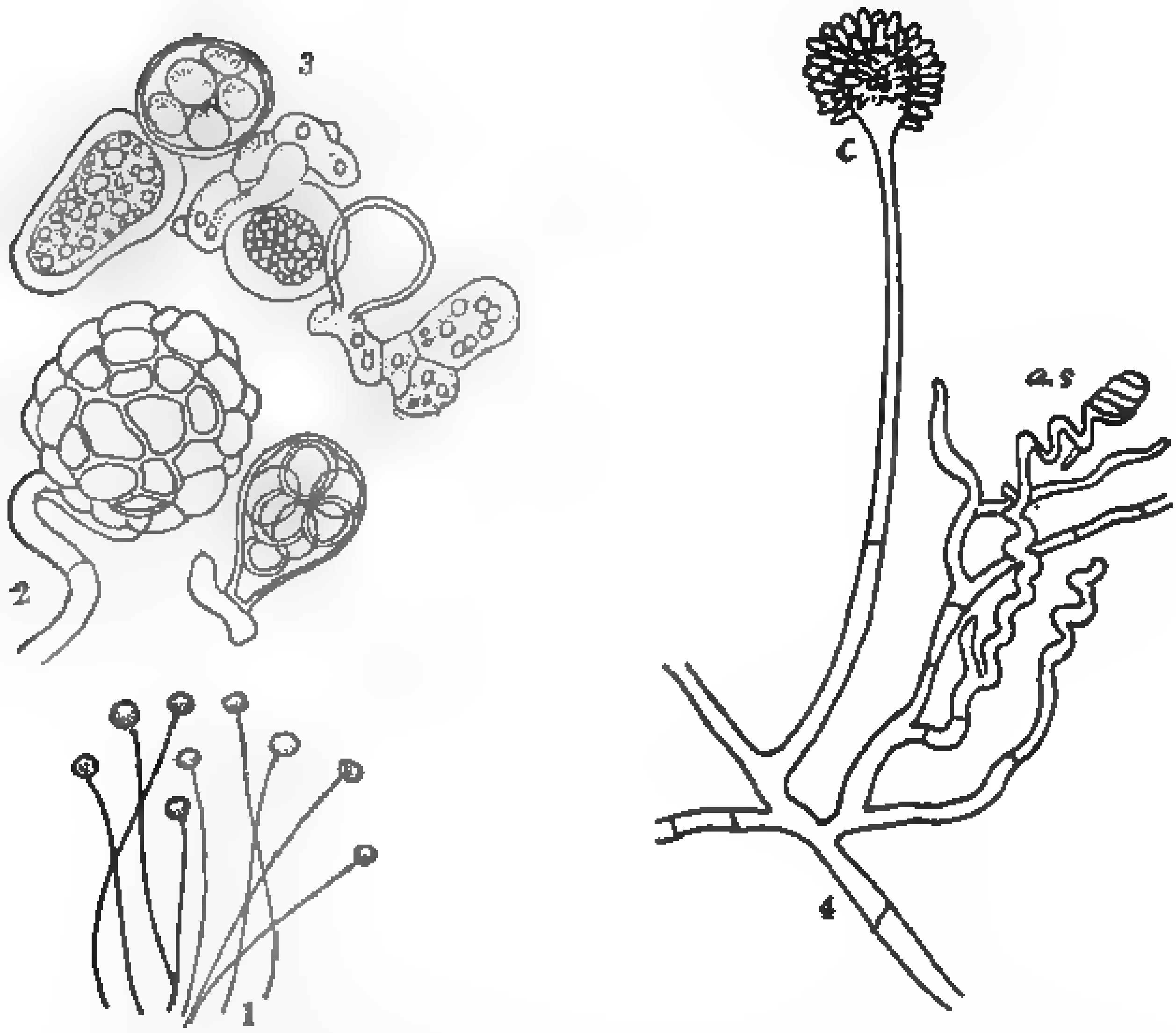

Fig. 68. Common Herbarium mould. (1) general appearance, showing long conidiophore and sterigmata on end; (2) perithecium with one of its asci and ascospores; (3) contents from an unripe perithecium; (4) a small part of a mycelium with conidiophore c, and spore bearing sterigmata, young ascogonium a. s. (DeBary except 1.)

mycelium enters the kernel because of the dissolving action of an enzyme produced by the mycelium. From this mycelium erect threads (conidiophores) arise. These are enlarged at the end. From the enlarged portion of the conidiophores numerous small and radiating stalks (sterigmata) are produced, each bearing a chain of spores, the end spore of the chain being the older. These spores germinate under favorable conditions of moisture and heat, and again give rise to the same stage. In addition to this, the condidial stage, a second kind of reproductive body occurs. This is produced by the coiling of a branch of the mycelium having several turns. Two or three slender branchlets grow from the base. One of these grows more rapidly and connects with the top of the spiral coil formed first. The contents of those last formed unite with the spiral known as the ascogonium. After fertilization a perithecium is produced.

This contains the asci. Each ascus is surrounded by a delicate wall and contains eight biconvex ascospores.

Rhizopus nigricans. Ehrh.—The third mould commonly found is the black mould. The mycelium spreads over the tissue, and on the surface small black bodies, the sporangia, are produced. The conidiophore arises from the felted mycelium. The conidiophore bears an enlarged spherical head, the sporangium, within which occur the spores. On adding water to the specimen, the wall of the sporangium collapses and the end of the stalk, known as the columella, turns back, giving it something

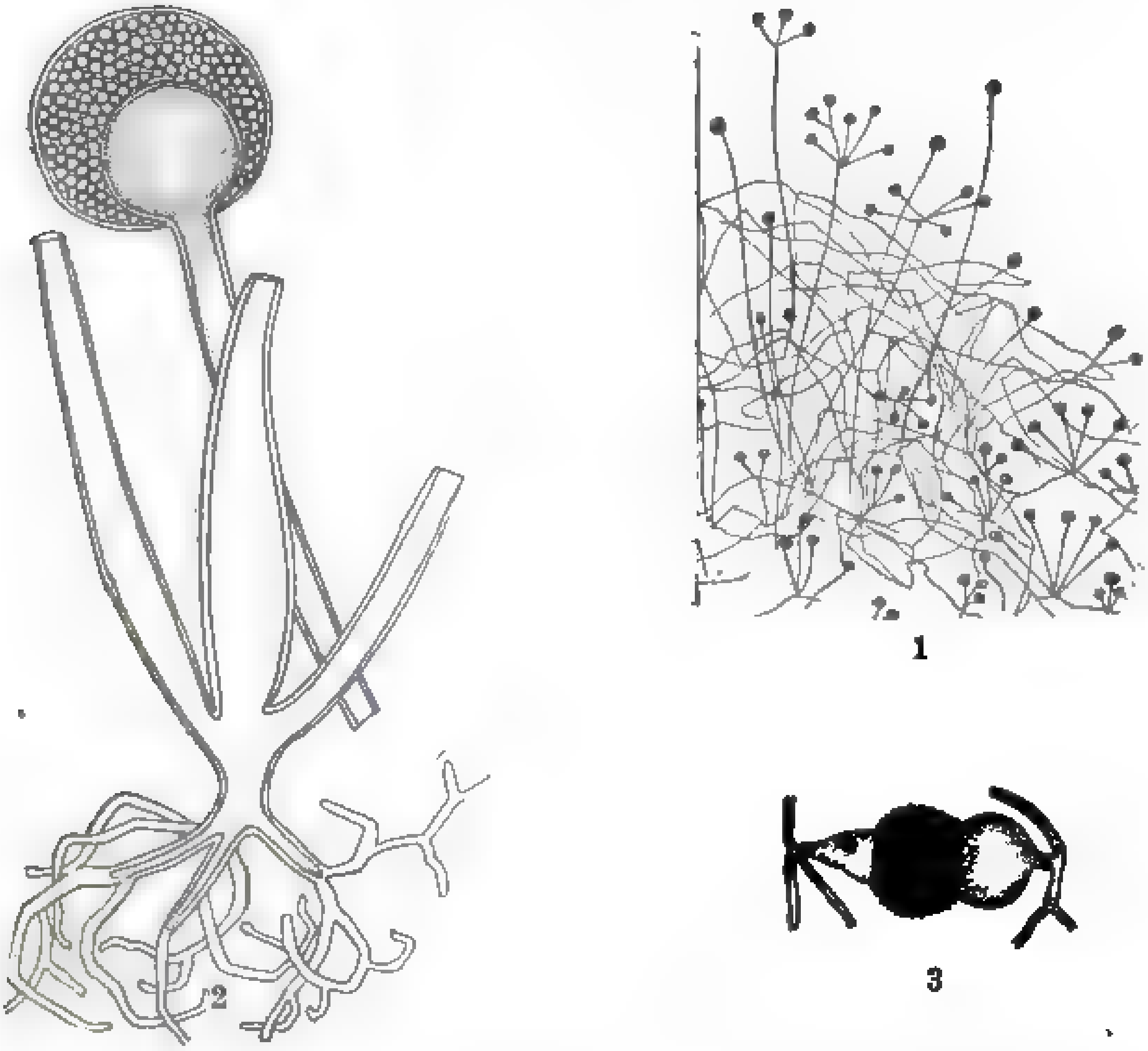

Fig. 64. (1) Common black mould (*Rhizopus nigricans*) showing sporangia and method of spreading by stolons. (2) *R. nigricans* showing rhizoids, conidiophore, columella, sporangium and spore. (3) Zygospores of one of the mucoraceae showing method of conjugation.

of the appearance of an umbrella. The columella before it collapses projects into the sporangium. The spores germinate readily when placed in a moist atmosphere. In addition to the production of a sporangium a stalk may bend over and cause the further extension of the fungus by producing what is

known as a stolon. The old name for the fungus, *Mucor stolonifer*, was given to it because of the production of these stolons. In addition to the formation of spores in the sporangium, zygospores are produced in certain races. Two threads of the mycelium lying in proximity and nearly parallel, each produces a tube. These meet, the walls are absorbed, and just back from the meeting point a cell is cut off. The contents from the old cells pass into the newly formed cell. We also observe that the cell of one arm is somewhat smaller than the other. This spore is a resting spore or zygospore. It lies dormant for a period, then germinates by forming directly a conidiophore with its sporangium containing the spores.

Bacteria.—In an examination of mouldy corn, bacteria have been found in large quantities, but none of these have been studied sufficiently to speak of the power they have in causing rot. Prillieux* states that wheat is often covered with a bacterial organism that produces a red coloration. Not enough, however, is known of this organism to say whether it is the cause of the disease mentioned by him or not.

The first step in the germination of corn, as said before, is the absorption of water. If the embryo is vigorous, and conditions are favorable, the young embryo will push through the testa and pericarp.

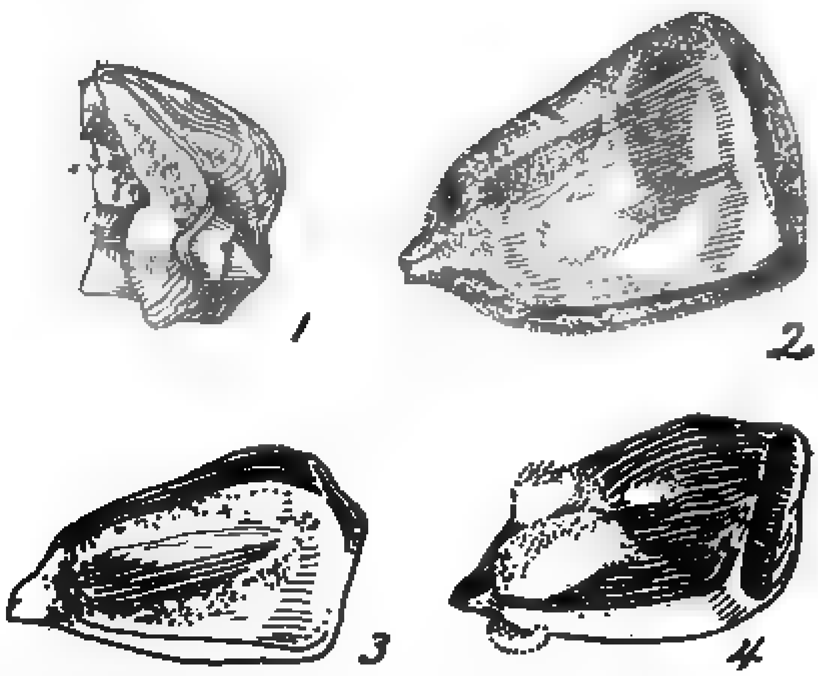

Fig. 65. Mouldy maize kernels. These failed to germinate. *1*, Sterigmatocystis; *2*, Aspergillus; *3*, Rhizopus; *4*, Penicillium.

On the other hand, if it is weak it is unable to do so. A cold, damp soil and frequent rains are not favorable for the embryo to push through, and hence the invasion of saprophytic

*Prillieux. Annal de Sci. Nat. Bot. VI. 7: 248.

fungi, for none of these organisms are truly parasitic. Much of the corn during the season of 1897 showed a fairly good percentage of germination, and yet the stand was very poor; the seed in fact rotted in the ground. This was due to the conditions above stated. Good germination requires warm weather, with sufficient rain so as not to dry out the seed.

CHEMICAL AND PHYSICAL INFLUENCES ON THE GERMINATION OF GRASS SEEDS.

Chemical.—It has been customary for a long time to treat wheat and other cereals with certain chemical substances for the purpose of preventing fungus diseases. They have also

Fig. 66. Copper compounds and the germination maize. U. S. Dept. of Agrl. formula, *12*, *13*; *5*, Bordeaux mixture full strength; *6*, Bordeaux mixture one-half strength.

been treated for other purposes. These purposes may be classified as follows; *First*, to hasten germination; *second*, to protect the seed from insect and other animal pests; *third*, to prevent the attacks of fungi; *fourth*, to furnish the young plants nourishment. It is very doubtful indeed if any kind of treatment with chemicals actually hastens the germination of seeds. Formerly a large class of substances were given which would support and hasten germination. The literature on this subject as given by Nobbe* states that the seeds of certain crucifers when in contact with chlorine germinated in from six to seven hours, while seeds placed in water germinated in thirty-six to

Fig. 67. Copper compounds and the germination of maize. U. S. Dept. of Agri. formula. 3, 4, treated with ammoniacal carbonate of copper normal; 1, 2, double normal.

*Samenkunde. 255.

thirty-eight hours,but Otto* makes the statement that with oxalic acid he succeeds in causing seeds to germinate which were between 20 and 40 years old. Bailey,† who treated a large number of chemicals with substances as permanganate of potash, chlorate of potash, etc., demonstrated that these retarded rather than hastened germination. In a paper by Pammel and Stewart‡ on the subject of corn and different fungicides it was shown quite conclusively that the treatment in every case was injurious.

Pammel§ had previously shown that corn roots, when treated with a mixture containing copper salt, were injuriously affected, the total amount of germination being retarded. These experi-

Fig. 68. Copper compounds and the germination of maize. Strong ammoniacal carbonate of copper.

ments were conducted in the greenhouse. Dr. Walter H. Evans,‖ in a compilation of the treatment of seeds with copper sulphate, to prevent the attack of fungi, comments on this experiment as well as others. Evans seems to question the

*Balfour; Class book of botany. 3: 638.

†Ann. Rep. Mich. Agrl. Exp. Sta. 1: 110. 1888.

‡The influence of fungicides upon the germination of seeds. Agrl. Sci. 8: No. 5. 1894.

§Are copper salts injurious? Bull. Iowa Agrl. Exp Sta. 16: 221.

‖Copper Sulphate and germination. Bull. Div. Veg. Phy. and Path. U. S. Dept. Agrl. 10: 14.

result of the experiment. In order to show that there is no question in regard to these results, the accompanying figures show a marked difference between treated and not treated plants, kept under the same conditions. Quite a large number of experiments have been made in testing the effects of chemical solutions on the germination of corn, and it has been shown that quite a large number of salts act injuriously, and even a weak solution sometimes checks the germination of corn. The conclusions reached by several investigators are here given. It was very evident in some work conducted by Pammel and Stewart* with the copper compounds that even the very weak solution retarded and in some cases prevented germination.

Thus, for instance, when corn was soaked for two hours in ordinary copper sulphate solution, more than three-fourths would not germinate. Ammoniacal carbonate of copper was also used. When the corn was soaked in it for two hours only twenty-seven kernels out of 100 grew, but when the treatment was continued for only one hour fifty-seven kernels grew.

In an exhaustive paper on the subject by Hitchcock† and Carleton,† they state in regard to ferrous sulphate that corn soaked for twenty-four, forty-eight and seventy-two hours, respectively, gives the following percentages of germination:

Time of immersion	24	48	72
Per cent	24	20	17

The germination was from 80 to 100 per cent of that obtained with water, but retarded. Prof. L. R. Jones‡ concluded that soaking corn in Bordeaux mixture for one hour and less, had no perceptible effect, and soaking six hours was slightly beneficial. Soaking in copper sulphate solutions, of either strength, for lengths of time up to fifteen minutes, did no apparent injury. Soaking one hour was slightly injurious. But, after all, the substances which have been experimented on, among them ferrous sulphate, have been widely used to better the soil. Mayer§ shows that 200 grams of iron sulphate acted injuriously on rye, barley and oats, and that 100 grams on wheat. This quantity of iron sulphate was added to sixteen kg. of soil.

*Agrl. Sci. 8: 215.

†Bull. Kansas Agrl. Exp. Sta. 41.

‡Ann. Report Vermont Agrl. Exp. Sta. 1891: 139-141.

§Nederlandsch Landb., Weekblad. 31: 2. 1892. Biedermann's Centr. Agrikulturch. 22: 158.

In regard to several other grasses Mr. Thompson* states of oats, clover, ray grass, corn, *Avena orientalis*, *Arrhenatherum, avenaceum* and *Medicago sativa* that sulphate of iron acts injuriously upon the development of the roots. Most of the earlier references are fully given in the review in the paper quoted by Pammel and Stewart as well as Evans.

Physical.—Maldiney and Thouvenin† have made some experiments to determine the influence of X-rays upon germination.

In the case of *Panicum miliaceum* the writers found that when under the influence of X-rays for two hours germination was hastened. The amount of moisture and physical condition of the soil are most important factors during the process of germination.

SEED SELECTION AND THE CROP PRODUCED.

There can be no question that the careful and intillegent selection of seed influences the crop. This has been amply demonstrated in a great many crops. It is a well-known fact that the European sugar beet growers carefully select "the mother beet" by making tests of the amount of sugar present. It has also been shown by Wiley‡ that by a careful selection of sorghum canes, with a high percentage of sugar, the standard has been raised. Mr. Oma Carr§ shows that in certain varieties the per cent of sugar content was increased as follows:

VARIETY.	1888.		1889.		1890.		1891.		1892.		1893.	
	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.	Sucrose.	Purity.
Amber...........	9 5	63	11.7	74	12.8	71	12.9	72	14.5	76	14.3	68.4
Colman...........			14 6	76	14.9	76	15.6	76	17 2	75	15.5	75
Orange...........	10.4	63	12.1	71	12.5	72	13.6	68	17.7	80	16.2	80

Wiley records several pedigrees of the improved canes and the amount of sugar they contain and gives a discussion of the results. Hicks and Dabney‖ have shown that there is a marked increase in the weight of seedlings of radish, early Amber cane, Kafir corn, winter vetch, sweet pea, rye, oats and barley from the heavier seed, that there is an increase in the root development when seeds are planted. In case of heavier peas early flowering is noticed. Webber says: "Mr. Henslow¶ found

*Ueber die Wirkung von Schwefelsaurem Eisenoxydul auf die Pflanze. Dorpater Naturforscher-Gesellschaft. 18: 96-101.

†De l'influence des rayons X sur la germination. Revue generale de bot. 10: 81.

‡Experiments with sorghum. Bull. U. S. Dept. Agrl. Div. Chem. 29: 52. 39: 25. 40: 27.

§Experiments with sorghum. Bull. U. S. Dept. Agrl. Div. Chem. 40: 28.

‖Year book. U. S. Dept. of Agrl. 1896: 305.

¶Year book. U. S. Dept. of Agrl. 1896: 89.

that seedlings of large seeds, owing to their greater vigor, crowd out the seedlings of small seed. A continual selection of the small seeds for several generations, he says, will cause the plants to die out altogether by failing to produce seed, or else a tiny race of beings will, for a time, be maintained. These vegetable runts, the result of insufficient nutrition and insufficient light, are of common occurrence in nature." B. T. Galloway, by growing selected lots of large and small radish seed, found that "the largest seeds germinated more quickly and with more certainty, and produced marketable plants sooner and more uniformly than the small seeds." The latter, however, "gave porportionally larger plants." In this case, which at first thought seems confusing, we see, as Mr. Galloway suggests, the effect of long continued, natural methodical selection. The radish is cultivated for the root, and selection has been continually directed to increase the size of this part without attention to the seeds. If more nutrition is utilized in root development with plants of equal vigor, less would probably remain for seed development, resulting naturally in small seed. Thus, long continued selection, aiming only to increase the size of the root, which is done with some detriment to the seed, might be expected to ultimately lead to an inherited tendency of the small seeds to develop large plants, and vice versa." The subject of corn from this standpoint, has been quite fully treated by Arthur and Golden.*

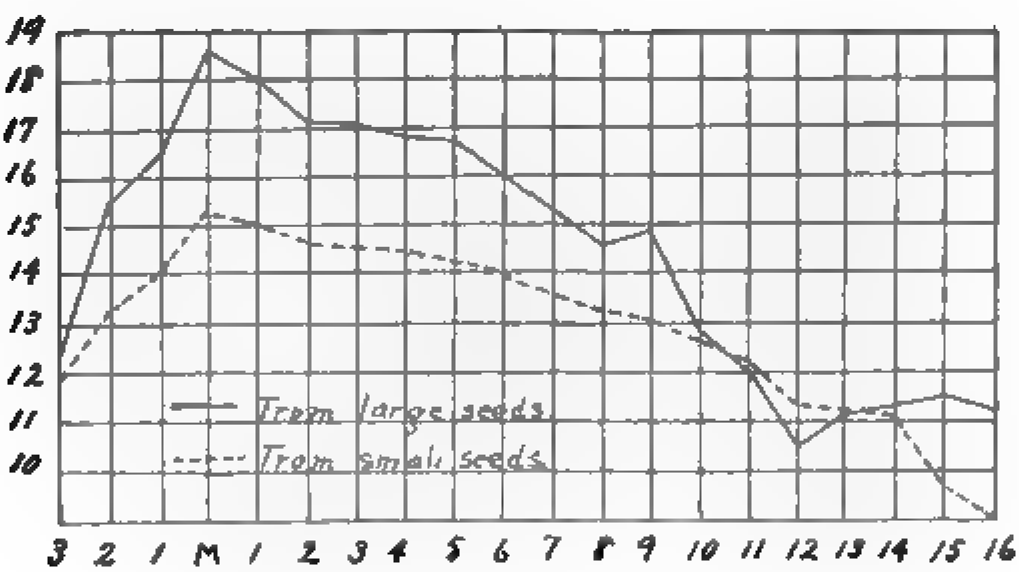

Fig. 68. Product from large and small seeds. (Arthur and Golden.)

*Agrl. Sci. 5: 117.

They have given numerous references to the work of European and American investigators. Among the latter we desire especially to mention the works of Goff* and Latta.†

The work of Arthur and Golden is in the line of our own work. We quote from their results as follows: "Thirty kernels from a single ear of white dent corn were separately weighed, of which six grew that were over 400 milligrams each, and nine that were under 300 milligrams each. The product of these gave a greater average weight of ears for the large than for the small seed, which was also true of the cobs and kernels taken separately."

	Product of large seed.	Product of small seed.
Average weight of seed in milligrams	312	268
Average weight of cobs in grams	55	47

The accompanying graphic illustration of the results brings out the difference in the weight of the kernels even more strikingly. The solid line indicates the product from the large seed and the interrupted lines from the small seeds. The diagram as a whole shows the variation at different parts of the ear, the butt being to the left and the tip to the right.

"The kernels from each ear of the product were removed and weighed by fifties, beginning at the end of the ear and proceeding in order to the other. The average of all of the heaviest fifties, one from each ear, gave the maximum weight, marked M in the diagram. The average of the fifties ranging first, second, third, etc., right and left of the maximum was then found. Thus the diagram represents the difference of the weight of the kernels of the ear in the order they occupied on the cob, the butt of the ear lying to the left and the tip to the right of the diagram.

The figures below the diagram indicate the position of each fifty seeds on the ear; the figure at the left gives the average weight in grams of fifty seed. Webber‡ states that "Roujon,

*Ann. Rep. N. Y. Agrl Exp. Sta. 3: 199. Ann. Rep. N. Y. Agrl. Exp. Sta. 4: 181. 128, 120.

†Bull. Indiana Agrl. Exp. Sta. 37: 32: 14.

‡Influence of environment in the origination of plant varieties. Year book U. S. Dept. Agrl. 1896: 92.

by selecting and planting only the smallest seeds from the least developed specimens of sunflower, corn and other plants, obtained in two years very small plants. The corn was reduced in size to about eight inches high. As the height diminished the number of seed decreased, and the final result was absolute sterility."

In the case of corn, farmers have done a great deal towards selection by saving the best for seed. There has been much discussion as to whether the kernels found at the base are better than those at the tip. Tests made at the Kansas Agricultural Experiment Station* show: "Considering all the facts shown in this experiment and in the experiment with corn planted at different distances, the inference seems plain that we must plant corn with the sole object of raising grain, or with the sole object of raising feed." The average of three years' trials are slightly in favor of the butt kernels, according to Georgeson, Burtis and Otis.†

Cereals.

The importance of cereals as a crop in Iowa merits a separate consideration. This is especially necessary in the case of the more important. The term cereal is applied to all members of the grass family in which the grains are used for food. Some of the more important works which consider cereals and cereal culture are as follows:

Koernicke‡, Metzger§, Seringe‖, Hackel¶, Darwin**, DeCandolle††, Beal‡‡, Wallace§§, Brewer‖‖, Emmons¶¶, Klippart***,

*Bull. Kansas Agrl. Exp. Station. 30: 1891.

†Bull. Kansas Agrl. Exp. Station. 45: 143. 1893.

‡Koernicke-Werner. Handbuch des Getreidebaues. Koernicke Die Arten u Varietaten d. Getreides 1: 470. *pl. 10.* 1885. Werner, Die Sorten u. d. Anbau d. Getreides 2: 1010. 1885.

§Europaische Cerealien. In botanischer und landwirthschaftlicher Hinsicht bearbeitet 74. *20 pl.* Mannheim. 1824. Heidelberg.

‖Seringe. Cereales Europennes. 1841. Monographie des Cereales de la suisse. 1819. Berne and Leipzig.

¶Hackel. True grasses. English Translation Lamson-Scribner and Southworth, 228. 110 1890. Hackel. Gramineae in Naturlichen Pflanzenfamilien II. Theil. 2 Abth.

**Darwin. Charles. Animals and Plants under domestication. 1: 320-341.

††DeCandolle, A. Origin of cultivated plants. English translation 468. 1892.

‡‡Beal, W. J. Grasses of North America. 1: 457 f. 175. 1887. (Ed. 1.) 457. 175. 1896. (Ed. 2.)

§§Wallace. India in 1887. 363. *71 pl. 5. f. 1 map.* 1888.

‖‖Brewer. Report on the cereal production of the U. S. 10th Census of the U. S. 3: 173. *16 maps.*

¶¶[10]Emmons. Agriculture of New York in Nat. Hist. N. Y. 2: 90-274. *pl 26-28.*

***Klippart. Essay on the origin, growth, diseases, variety, etc., of the wheat plant. Ann. Rep. Ohio St. Board of Agrl. 12: 562-816. 11 pl. 1857.

Simmonds*, Harz†, Tschirch and Oesterle‡, Snyder and Voorhees§, Neftel‖, Plumb¶, Hehn, **Williams††, Lamson-Scribner‡‡, Buschan§§.

paper on maize, thinks, from evidence of archaeology, history,

Maize. (*Zea Mays*, L.)—Harshberger published an extended ethnology and philology that central and southern Mexico is the original home of maize. This is supported by the facts of botany and meteorology. Several closely related genera are of Mexican origin, as *Euchlaena* and *Tripsacum*. The latter genus occurs as far north as southern Iowa. Naturalists generally agree that closely related species and genera had their origin from some common progenitor.

The Indians probably first found the plant in the region above 4,500 feet altitude and south of 22° north latitude and north of the river Coatzacoalcos and the isthmus of Tehuantepec. It probably reached the Rio Grande about 700 A. D., and by the year 1000 had reached the coast of Maine. It was introduced into Europe soon after the discovery of America.

Rye (*Secale cereale* L.)—Rye has not been long in cultivation, according to DeCandolle‖‖, unless perhaps in Russia and Thrace. It has not been found in the Egyptian monuments and there is no name for it in the Semitic languages, nor Sanskrit, nor the languages derived from Sanskrit.

It appears to have originated in Europe, where it was anciently cultivated, and it is probable that it originated in the regions between the Austrian Alps and north of the Caspian sea. The other known species of the genus Secale inhabit western central Asia or the southeast of Europe. In central Asia rye is spontaneous and grows as thickly as though sown.

Barley. (*Hordeum sativum*, *Jessen.*)—This cereal is without doubt one of the most ancient of cultivated plants, and is supposed to have originated from *H. spontaneum*, Koch, which

*Simmonds, P. L. Tropical Agriculture. 515. 1877.

†Harz. Landw. Samenkunde. 1: 552. 2: 552-1362.

‡Tschirch & Osterle. Anatomischer Atlas der Pharmakognosie und Nahrungsmittelkunde. 41, 42, 43, 44, 45, 52, 53.

§Snyder & Voorhees. Studies on bread and bread-making. Bull. of U. S. Dept. of Agri. 67: 56.

‖Neftel, Flour milling process. 10th Census Rep. 3: 22. 6 pl.

¶Plumb. The Geographic Distribution of Cereals in North America. Bull. Div. of Biological Survey. U. S. Dept. of Agri. 11:24. *pl. 1*.

**Hehn. Kulturpflanzen und Haustiere. in ihrem Uebergang aus Asien nach Griechenland und Italien sowie in das ubrige Europa. 582. 1887.

††Williams. Millets. O. Exp. Sta. Farmer's Bull. U. S. Dept. of Agr. 101: 28. 6.

‡‡Lamson-Scribner. Grasses of Tennessee. Bull. Agr. Exp. Sta. Tenn. 5: 2.

§§Buschan. Vorgeschichtliche Botanik d. Cultur. u. Nutzpflanzen d. alten Welt auf grund prahistorischer Funde. 268. 1895.

‖‖DeCandolle Origin of Cult. Pl. 370.

Fig. 68 A. Rye with details of flower and spike. (Nees from Hackel.)

Fig. 68 A A. *Zea canina*, Watson, grown at Knoxville, Tenn. Original of cultivated maize. (Photograph, F. Lamson-Scribner.)

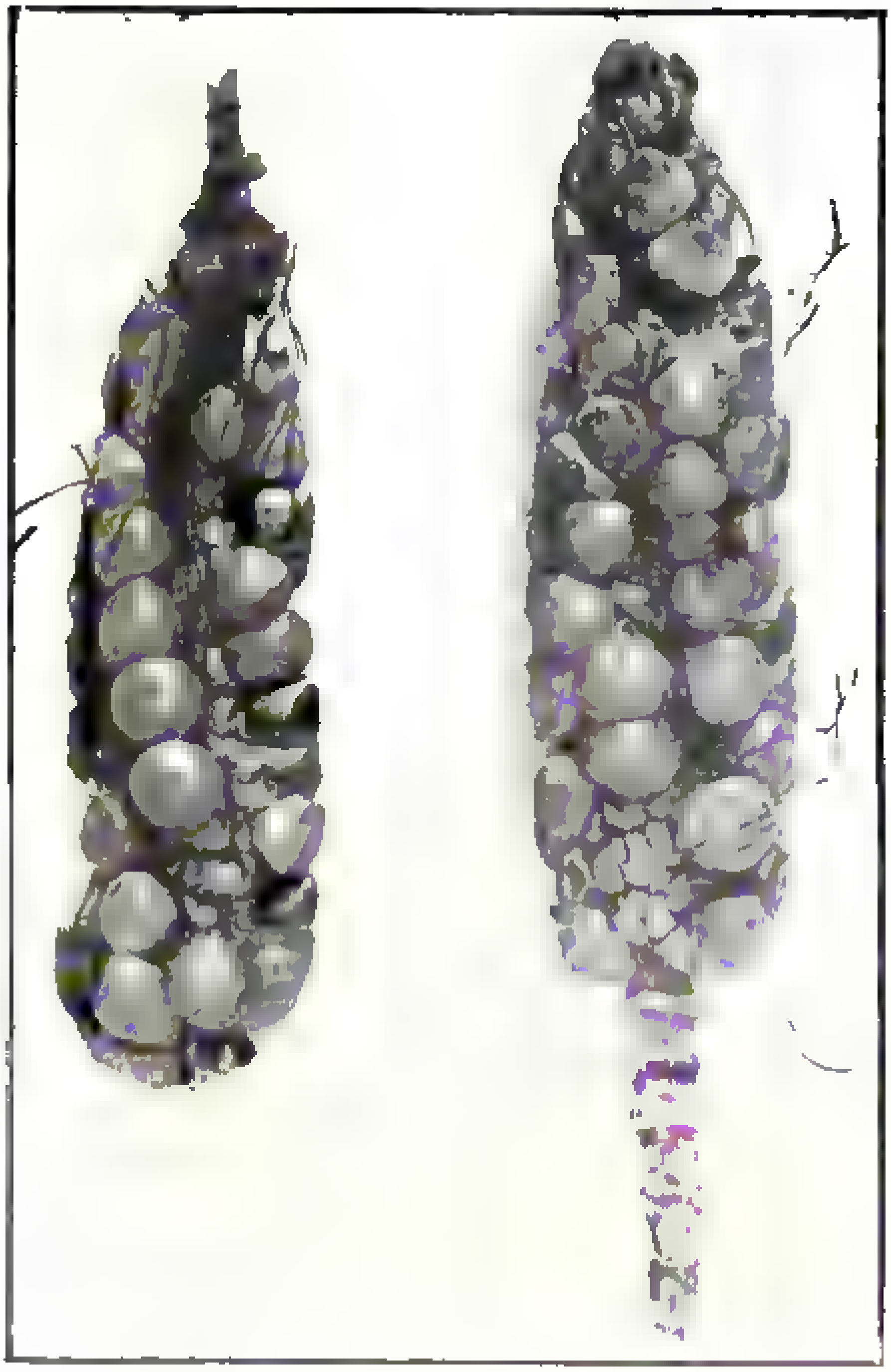

Fig. 69 B. *Zea canina* grown at Knoxville, Tenn. showing cob and kernels. (Photograph, F. Lamson-Scribner.)

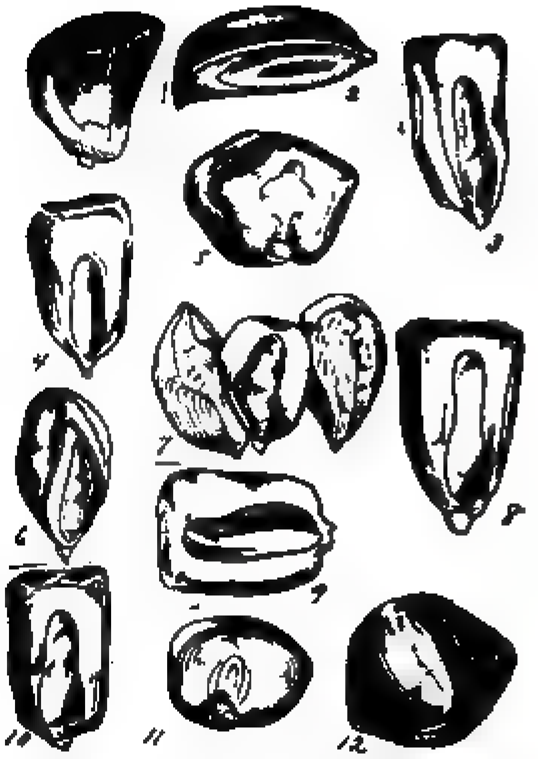

Fig. 68 BB. Different varieties of maize. *Zea mays.* (1) Mexican; (2) Mexican; (3) Dent legal tender; (4) Dent; (5) Sweet; (6) Pop; (7) Husk maize with bracts removed; (8) Dent, mortgage lifter; (9) White dent; (10) Dent; (11) Flint; (12) Black Mexican sweet. (King.)

Fig. 69. Wheat, *Triticum sativum.* Common bearded winter wheat, Triticum sativum vulgare 2. Triticum sativum vulgare muticum. (Hackel.)

Fig 69 AA. Polish wheat, *Triticum Polonicum* 2 Bearded spelt. *Triticum sativum spelta.* (Hackel.)

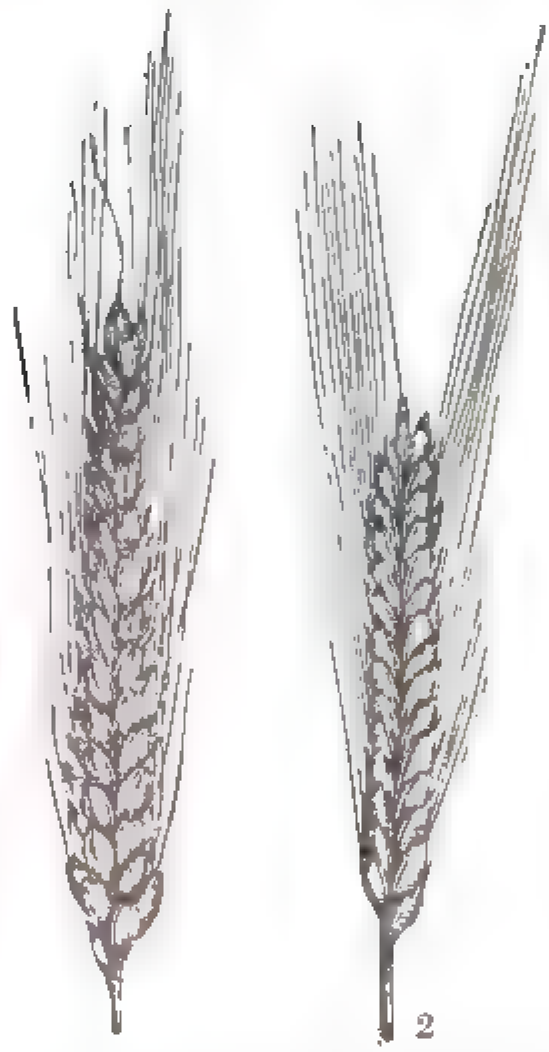

Fig. 69 A. "German wheat," *Triticum sativum dicoccum.* 2. One-grained wheat, *Triticum monococcum,* L. (After Hackel.)

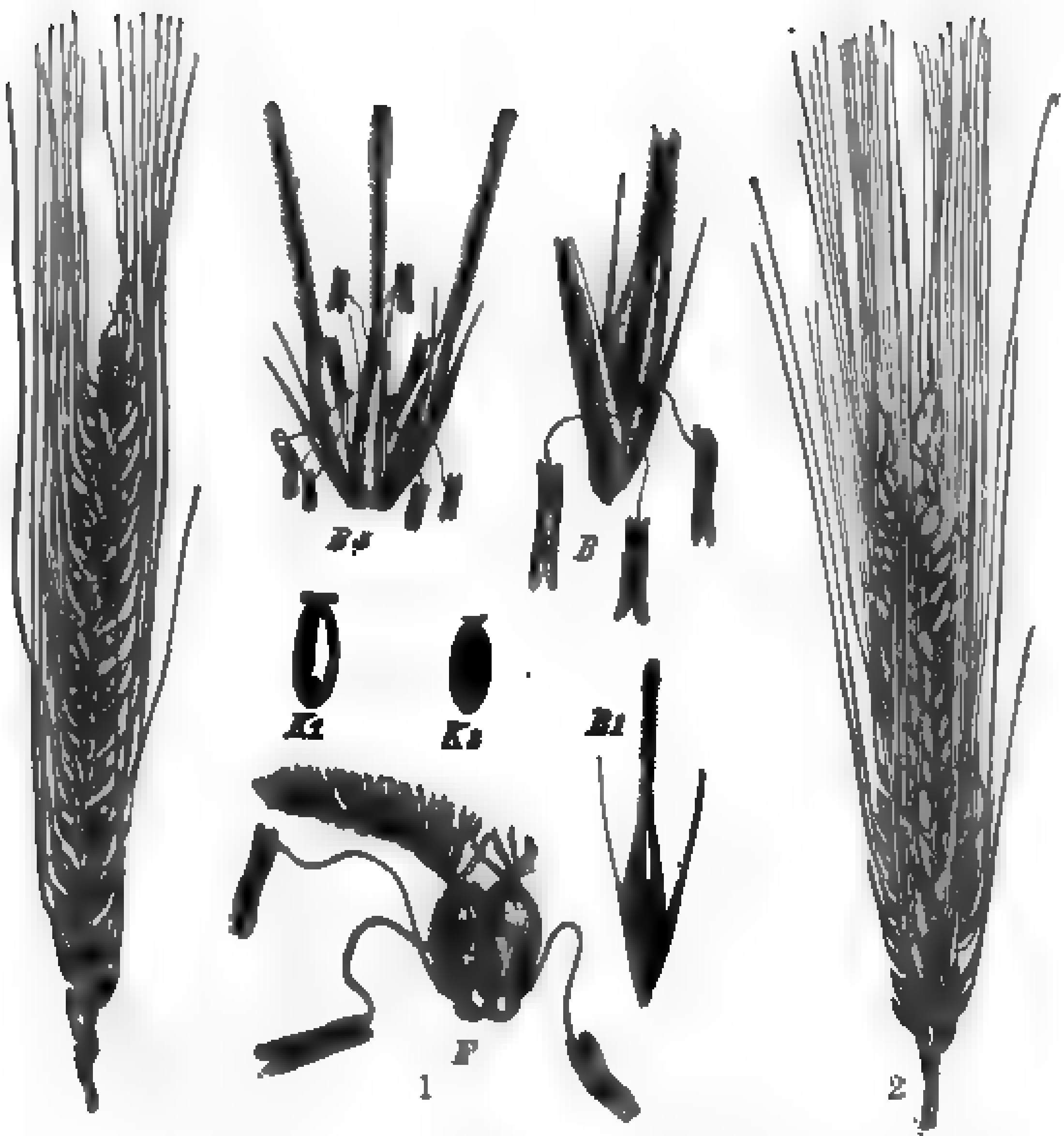

Fig. 60 B. Two-ranked barley, *Hordeum sativum distichon*. (After Hackel.)
1, *Hordeum sativum hexastichon*. (B 3) group of three spikelets; (B) spikelet from behind; (B 1) from in front; (K 1) fruit from in front; (K 2) from behind. (After Nees.)
2. Common four-rowed barley, *Hordeum sativum vulgare*. (After Hackel.)

Fig. 69 BB. 1, English wheat, *Triticum sativum turgidum*. 2, Flint wheat, *Triticum sativum durum*. (After Hackel.)

grows wild in Asia Minor and Caucasian countries to Persia and Beloochistan as well as Syria and Palestine.

Wheat. Triticum sativum, Lam.—The only form known in a wild condition is the *T. monococcum, L.* Cultivated wheat is prehistoric. Several of the forms are of great antiquity. The ancient Egyptian monuments contain abundant specimens of wheat. The Chinese grew wheat 2,700 years before Christ. The Hebrew scriptures contain records of prehistoric wheat. Wheat was frequently used by the Lake Dwellers of west Switzerland.*

The Polish wheat, *Triticum polonicum*, a form obtained by cultivation, probably originated in modern times. The Spelts, *Triticum spelta*, probably was cultivated to some extent by the ancient Romans and Greeks, but there is some question in regard to it. *T. monococcum* was probably anciently cultvated, siince it is mentioned by some of the ancient writers. The seeds were found among the Swiss Lake Dwellers. The Romans did not cultivate it. It is probable tha it was introduced from Asia Minor to Spain, and from there to France and Germany.

Oats. Avena sativa, L.—This is a comparatively modern plant. It certainly was not cultivated by the Egyptians or Hebrews, nor was it cultivated very anciently in India, as there is no Sanskrit name for the plant. Its cultivation in India is carried on chiefly by the English. The ancient Greeks knew it by the name of Bromus and the Romans, Avena. Pliny's remark that the Germans lived on oatmeal seems to show that its cultivation was carried on north of Italy and Greece. Apparently it later became diffused to the south in

*De Candolle. Origin of Cult. Pl. [illegible]

the Roman empire. That its culture is very ancient with the Kelts is shown by the fact that the inhabitants of the Orkney and Shetland islands have long used it.

Fig. 69 O. Oats, (From Iowa Seed Co.)

Sorghum and Kafir corn. (*Andropogon sorghum*) Brot.—The original home of *Andropogon sorghum* is tropical Africa where durra is cultivated. It is frequently cultivated in Asia, but Linnaeus supposed it to be of Indian origin. It certainly was not cultivated anciently there, since there are no ancient names

Fig. 70. *Andropogon sorghum* and some of its varieties. *1*, Kafir corn; 2, Jerusalem corn; 3, Amber sorghum. (Kansas State Board of Agrl.)

for it, nor could it have been anciently cultivated in Europe, since the Lake Dwellers did not use it, nor did the writers of ancient Greece or Italy speak of it. The durra in its allied forms is wild in tropical Africa, and there is every reason to believe that its culture spread from South Africa to Europe and Asia.

Foxtail millets.—These millets belong to the genus Setaria or Chaetochloa. Some writers consider the Hungarian millet (*Setaria Germanica*) distinct from the German millet, *S. Italica.* The millets are of very ancient culture in temperate parts of the world and have been grown since prehistoric times. The grain seems to have existed in a wild form in China and Japan and in the Indian Archipelago, and early spread to India, where ancient Sanskrit names occur. In China this is one of five plants which the emperor* sows each year in a public ceremony, according to a command given by Chin-nong 2700 B. C.

De Candolle thinks that the Lake Dwellers of the stone age seem to have known the Setarias. It was also anciently cultivated in China, and the *S. germanica* seems to have escaped from cultivation in Japan. By some writers it is supposed to have originated from *S. viridis*, Beauv., our common foxtail or pigeon grass.

*De Candolle. Origin of Cult. Pl. [illegible].

Common or broom corn millet. Panicum miliaceum, L.—This plant is likewise of prehistoric culture, especially in Europe, Egypt and Asia. The Greeks and Romans were familiar

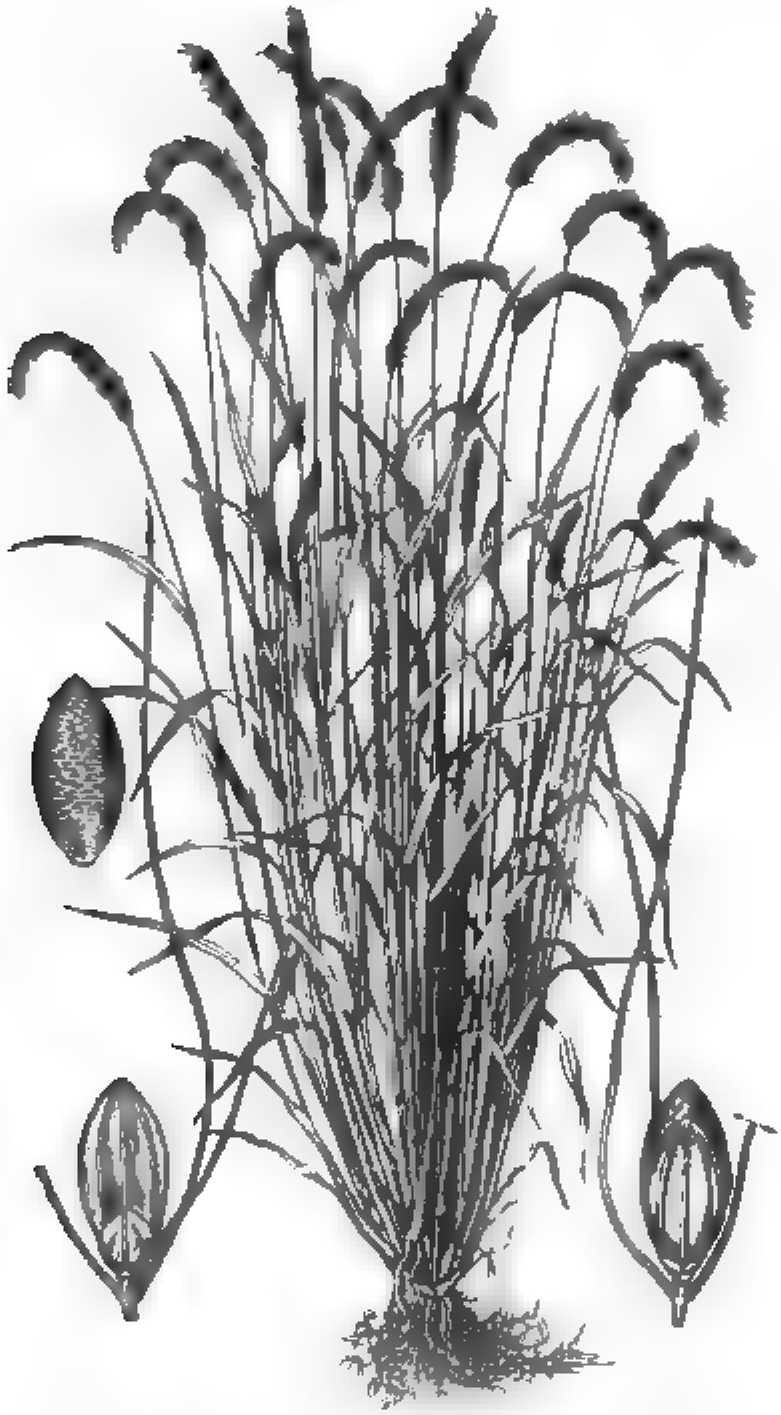

Fig. 70 A. Corean Foxtail millet. (Div. of Agrostology U. S. Dept. of Agri.)

with it. The Lake Dwellers during the stone age used this millet to a considerable extent. Its culture is thought to be very ancient in eastern Europe.

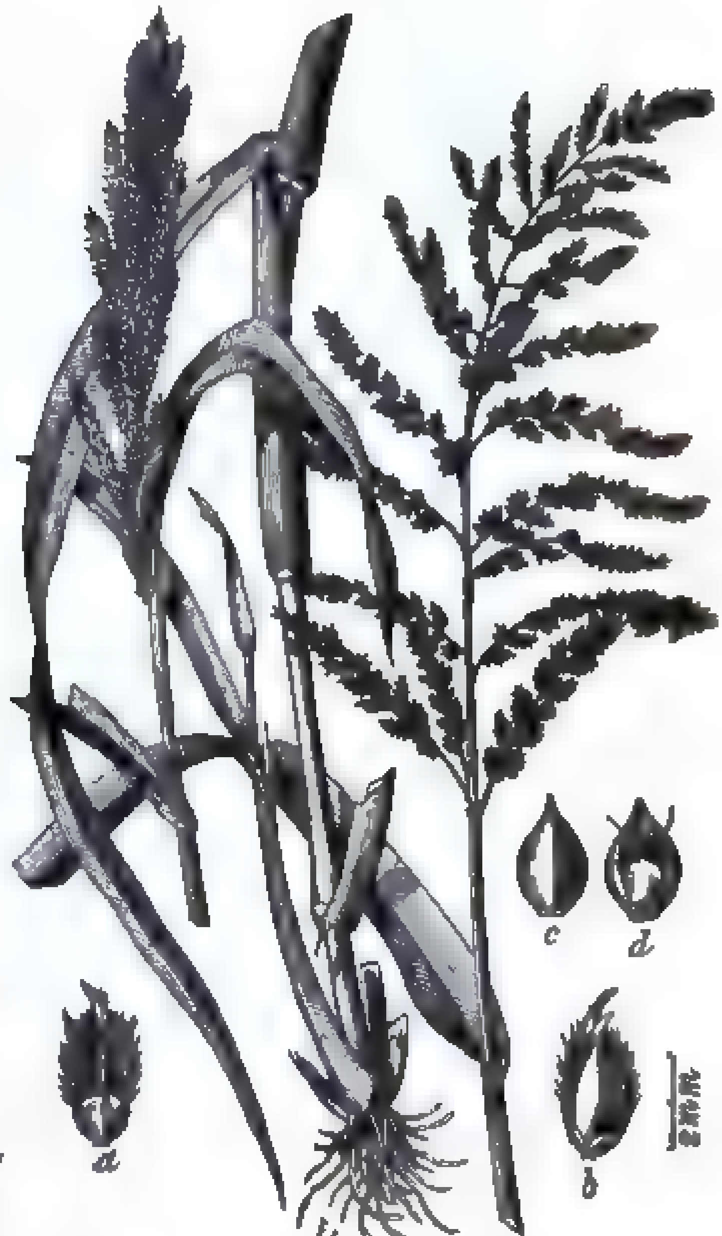

Fig 71 A. Ankee millet (*Panicum crus galli*), *a*, *b*, two views of the spikelet,*c*, *d*, twoviews of the seed. (After Div of Agrostology U. S. Dept. of Agrl.)

Fig. 71 B. Shama millet (*Panicum colonum*), *a*, *b*, *c*, *d*, different views of the spikelet and glumes; *e*, *f*, two views of the "seed." (Div. of Agrostology U. S Dept. of Agrl.)

Fig. 71 BB. Broom corn millet. (Div. of Agrostology U. S. Dept. of Agrl.)

Although there is some doubt in regard to its cultivation in China, some writers think it is one of the grains planted at the annual ceremonies, instituted by the emperor Chin-nong. It was early introduced into India and was at one time one of the most important cereals grown in France. It probably originated in the Egypto-Arabian countries.

Barnyard grass, Panicum crusgalli L.—This species is indigenous to Europe and extending to Asia, and now well-known as a cosmopolitan weed. It is extensively used as a forage plant in Japan. Of the other barnyard millets the Ankee is used quite extensively in the north and northwest. The Mohave Indians are said to use this seed very extensively for food. In warmer parts of Asia several other species of Panicum are used, especially *Panicum indicum* L. The Sanwa millet (*P. frumentaceum* Roxb.) and *P. colonum*, the Shama millet or Jungle rice, native to the tropics and sub-tropical countries of the old world. It has become naturalized in the warmer parts of the United States. It is a native to Asia and is extensively grown in India. Crab grass (*Panicum sanguinale*) was anciently cultivated as a cereal but its culture in modern times has almost entirely ceased. It was apparently never used very extensively. It is said to have been extensively cultivated in Bohemia and used for soups, and still finds use in that country.

The term Millets. This is applied to a number of grasses. The term barnyard millet was first applied by Brooks* and later adopted by Williams.† Williams has extended the use to not only those millets which originated from common barnyard grass but to varieties and species closely allied to it.

*Ann. Rep. Mass. Hatch Agrl. Exp. Sta. 8: 31.

†Year book of the U. S. Dept. of Agr. 1898: 276.

Elsewhere the statement has been made that the millets are important cereal crops. The more important of these are the *Setaria italica* and the *S. germanica*. The common foxtail millets grown in the United States are grouped under the following standard varieties:

Fig. 71 O. German millet (*Setaria italica*), *a* and *b* two views of the spikelet with three bristles; *c* seed. (Div. of Agrostology U. S. Dept. of Agrl.)

(1) Common millet. (2) German millet. (3) Golden wonder millet. All belong to *Setaria italica*. (4) Hungarian millet belongs to *Setaria Germanica*.

Sorghum mill ·ts are extensively grown in south Africa, Kansas, and Asia. Broom corn millet, *Panicum miliaceum*, is grown quite extensively as a cereal plant in India and China. The other millets here mentioned are grown chiefly in older Asiatic countries.

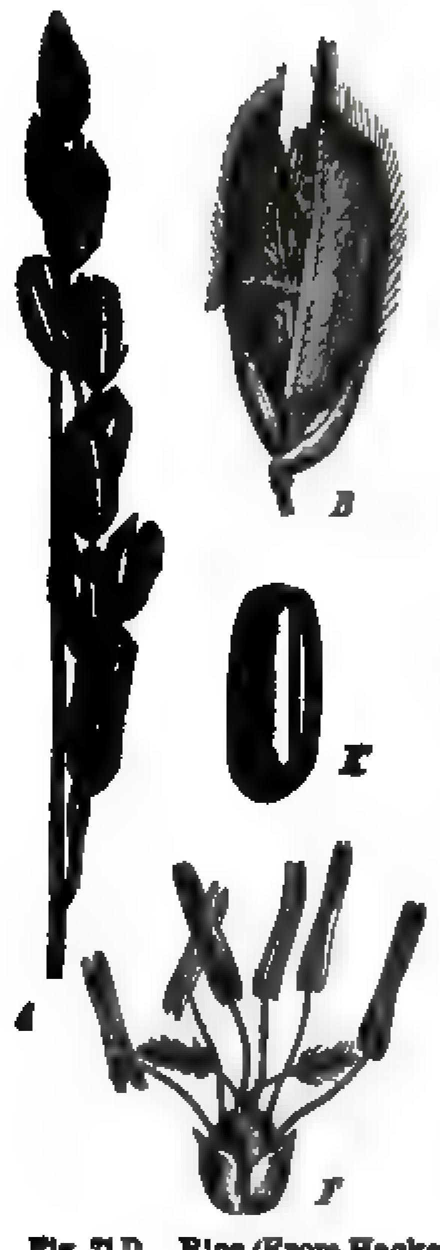

Fig. 71 D. Rice (From Hackel True Grasses.)

Fig. 71 E. Pearl Millet (From Hackel True Grasses.)

Rice (*Oryza sativa*, L.)—In China it was one of the cereals used by the emperor Chin-nong, 2800 B. C., in fact it was the principal cereal and by the Chinese it is supposed to be indigenous. Its cultivation in India was later, but DeCandolle is inclined to think that it may have been indigenous to that country as well as China.

Pearl millet. Penniostum typhoideum, Rich.—This is an important agricultural grass in central Africa although its original home is not known. It is believed, however, that it originated in Africa and it is possible that the wild form can still be found there.

Coracana or ragi. Eleusine Coracana, Gaert.—The ragi of the inhabitants of Hindoostan is scarcely grown as a cereal outside of India, though in addition to its growth in India it is also found in Malay, Egypt and Abyssinia. The plant is of tropical origin and without doubt originated in India from the *E. indica*. A nearly allied species, if not identical, the *E. tocussa*, Fres., originated in Abyssinia. The ragi grows well under unfavorable conditions and therefore is used extensively in India.

Manna-grass. Glyceria fluitans, R. Br.—Manna-grass is a cosmopolitan aquatic grass and in parts of Europe, Prussia,

Fig. 71 F. Manna Grass (Division of Agrostology U. S. Dept. of Agri.)

Silesia and Poland is cultivated. The fruit is used for the purpose of making mush.

Wild rice. Zizania aquatica, L.—This plant is indigenous to the Mississippi valley, extending as far south as Louisiana. It also occurs along the eastern coast of North America between

Fig. 71 G. Canary Grass (King)

New York and Massachusetts. It is most common, however, in the northern Mississippi valley. It is also found in eastern

Asia. While the plant is not cultivated, it is carefully protected by the Indians, and is found much in favor by the Aborigines as a cereal product.

Canary-grass. Phalaris canariensis, L.—The home of this grass is usually attributed to the Canary islands but it is probable that this assumption arises from the fact that the plant has received the common name of Canary-grass. It is more than probable that its culture originated in Spain. It grows wild in southern Europe, especially Sicily and Catalonia. It is used as a cereal only in some of the southern countries of Europe.

Upright sea lime grass. Elymus arenarius.—This large grass is common along the coast of northern Europe and the British islands and along our western coast as far south as Oregon.* Aside from its great value as a sand binder the seeds are used for food by the Digger Indians of the northwest. By the inhabitants it is called "Rancheria grass."

Bamboos. Bambusa, Schreb.—The seeds of several species of bamboos are used in East India like rice. It is said by

Fig. 72. Tef (*Eragrostis abyssinica*) grown on college grounds. I. S. C.

*Lamson-Scribner. Year book. U. S. Dept. Agrl. 1894: 429.

Hackel that in Brazil and India misfortune follows the sudden production of such vast quantities of mealy seeds. Mice and rats increase at an extraordinary rate and after having eaten the bamboo fruits turn to the neighboring fields and devour the cultivated crops.

Tef. (*Eragrostis abyssinica*, Link).—Tef originated in Abyssinia. It is believed to have sprung from *Eragrostis pilosa*. It is now a cosmopolitan weed in temperate and tropical regions. It probably originated north of the equator in Africa. As a cultivated plant Tef is only used by the Abyssinians. The colored seeds have the appearance of grits, and the flour made from these is boiled into bread.

CEREAL PRODUCTION.

The chief cereal growing countries of the world is shown in the following table, taken from Broomhall,* of the Liverpool Trade *News*.

1896. IN MILLIONS OF BUSHELS.

	Wheat.	Corn.	Rye.	Barley.	Oats.
France	340	......	80	48	301
Russia, proper	300	†13	‡671	162	640
Poland	20	......	......	......	....
Caucasia	45	......	......	......	....
Hungary	140	140	118	......	....
Austria	42	......	......	106	186
Croatia and Slavonia	6	......	......	......	....
Herzegovina and Bosnia	2	......	......	......	....
Italy	134	74	4	8	26
Germany	110	......	244	116	370
Spain	70	......	......	......	....
Portugal	6	......	......	......	....
Roumania	80	64	12	30	17
Bulgaria	40	6	5	20	7
East Roumelia	8	......	......	......	....
Servia	14	......	......	......	....
Turkey in Europe	22	......	......	......	....
Greece	5	......	......	......	....
United Kingdom	59	......	......	77	194
Belgium	19	......	29	3	27
Holland	6	......	11	5	19
Switzerland	4	......	......	......	....
Sweden	5	......	23	14	65
Denmark	5	......	18	24	46
Norway	1	......	......	......	....
Cyprus, Malta, etc.	2	......	......	......	....
Europe, total	1,119				

*Herbert Myrick. Am. Agrl. Year Book and Almanac. 567.
†Fifty governments according to agricultural ministry.
‡Sixty governments according to agricultural ministry.

1896. IN MILLIONS OF BUSHELS—Continued.

	Wheat.	Corn.	Rye.	Barley.	Oats.
United States of America	590	2,270	24	70	717
Canada	60	18	......	16	114
Mexico	15	......	......	......	....
Argentina	60	80	......	......	....
Chili	16	......	......	......	....
Uruguay	6	6	......	......	....
Total America	747	......	......	......	....
India	205	......	......	......	....
Turkey-in-Asia	50	......	......	......	....
Persia	20	......	......	......	....
Japan	14	......	......	......	....
Total Asia	289				
Algeria	18	......	......	30	8
Tunis	6	......	......	4	....
Egypt	7	34	......	......	....
The Cape	2	......	......	......	....
Total Africa	33				
Victoria	7	......	......	......	....
South Australia	3	......	......	......	....
New Zealand	7	......	......	......	....
New South Wales	7	......	......	......	....
Tasmania	1	......	......	......	....
Other Australia	1	......	......	......	....
Total Australia	26				
World's total	2,388	2,705	1,239	733	2737

Cereal production in the United States.—It may be interesting in this connection to compare the production of the cereals of the United States, and finally comparing that with the state of Iowa. In this way will be shown the relation of Iowa to its sister states in the matter of cereal production. It will be most convenient to place these in the form of a table, and the table representing the crop production most easily accessible for 1897 is that prepared by Mr. Snow of the crop reporting bureau of the American Agriculturalist:

	IN THOUSANDS OF BUSHELS.												POUNDS.
	WHEAT.		CORN.		RYE.		BARLEY.		OATS.		SORGHUM.		RICE.
	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889.	1897.	1889	1889.
New York	8,680	8,304	15,480	15,100	....	3,065	....	8,220	44,356	38,896	....	....	....
Pennsylvania	23,151	21,598	39,[illegible]	42,318	....	5,763	....	495	37,169	35,197	....	....	....
Texas	7,174	4,288	68,[illegible]	69,112	....	63	....	46	24,045	12,661	....	....	....
Arkansas	2,862	955	33,427	33,982	....	18	....	....	7,608	4,180	....	....	....
Tennessee	11,458	8,300	60,904	63,[illegible]	....	165	....	63	11,300	7,355	....	....	....
West Virginia	6,616	3,634	14,349	598	....	117	....	5	2,294	2,948	....	....	....
Kentucky	14,440	10,707	62,880	73,434	....	632	....	165	12,573	8,775	....	....	....
Ohio	38,280	35,559	104,160	118,[illegible]	....	1,097	....	1,089	29,079	40,1[illegible]	....	....	....
Michigan	25,570; S 441	24,771	36,320	23,795	....	2,101	....	3,[illegible]	37,564	38,961	....	....	....
Indiana	33,[illegible]	37,318	114,750	10,948	....	377	....	250	33,[illegible]	13,461	....	....	....
Illinois	2,9[illegible]; S 906	37,[illegible]	234,900	229,[illegible]	....	3,[illegible]	....	1,197	109,041	137,[illegible]	....	....	....
Wisconsin	2,560; S 7,848	11,696	40,170	24,094	....	4,250	....	15,225	67,[illegible]	60,739	....	....	....
Iowa	2,570; S 14,754	8,249	81,605	313,130	....	1,445	....	13,406	132,447	146,679	....	....	....
Minnesota	1,113; S 52,951	52,300	238,750	24,696	....	1,[illegible]	....	9,100	58,244	49,958	....	....	....
Missouri	15,900	30,113	145,150	196,999	....	595	....	34	34,103	39,550	....	....	....
Kansas	62,047; S 2,610	30,399	160,940	259,574	....	2,017	....	165	25,543	44,629	....	....	....
Nebraska	2,496; 27,484	10,571	190,651	215,895	....	1,085	....	1,339	59,324	42,840	....	....	....
California	34,775; S 960	40,869	1,959	2,261	....	349	....	17,548	1,959	1,463	....	....	....
Oregon	7,014; S 11,566	9,286	495	229	....	69	....	674	5,089	5,949	....	....	....
Washington	8,767; S 11,759	6,345	276	156	....	10	....	1,269	3,290	2,373	....	....	....
Oklahoma	17,415	30	....	294	....	1	....	....	....	76	....	....	....
New England	290	....	....	....	....	....	....	....	....	....	....	....	....
North Dakota	45,455	26,406	395	176	....	19	....	1,870	16,553	6,773	....	....	....
South Dakota	30,395	16,541	25,[illegible]	13,153	....	65	....	903	15,750	7,469	....	....	....
New Jersey	....	1,829	....	8,657	....	575	....	1	....	2,897	....	....	....
Maine	....	79,636	....	260	....	6	....	....	....	3,066	....	....	....
New Hampshire	....	35,193	....	939	....	11	....	....	....	893	....	....	....
Vermont	....	164,730	....	1,709	....	42	....	....	....	3,316	....	....	....
Massachusetts	....	1,812	....	1,[illegible]	....	117	....	....	....	886	....	....	....
Rhode Island	....	99	....	253	....	9	....	....	....	190	....	....	....
Connecticut	....	7,459	....	1,471	....	214	....	....	....	595	....	....	....

	IN THOUSANDS OF BUSHELS												POUNDS.
	WHEAT.		CORN.		RYE.		[illegible]RLEY.		OATS.		SORGHUM.		RICE.
	[illegible]	[illegible]	1897.	1899	1897.	1899.	1897.	1899.	1897.	1899.	1897.	1899.	1899.
Delaware		1,501		3,097		6				333			
Maryland		8,843		14,838		338				3,019			
District of Columbia				10		1				1			
Virginia		7,904		27,172		397				5,095			
North Carolina		4,293		25,783		276				4,512			5,846,404
South Carolina		658		18,770		17				3,019			30,338,951
Georgia		1,095		29 261		57				4,757			14,556,433
Florida				2,701		13				891			1,011,806
Alabama		206		30,079		14				3,330			360
Mississippi		16		25,148		3				1,362			200,270
Louisiana				18,081						397			676,746
Montana		457		14						1,525			75,645,433
Wyoming		74		33		3				368			103,423
Colorado		2,845		1,611		54				2,514			7,110
New Mexico		243		668						199			
Arizona		100		33						33			
Utah		1,515		84		23				597			
Nevada		81		6						99			
Idaho		1,176		24		10				557			

Cereal production of Iowa.—The cereal produciton of the state of Iowa, as collected by Mr. J. R. Sage,* for the years 1894 and 1895 is as follows:

	WHEAT.		CORN.		RYE.		BARLEY.		OATS.		SORGHUM.		RICE.	
	[illegible]	1895.	[illegible]	1895.	1894.	1895.	1894.	[illegible]	1894.	[illegible]	[illegible]	1895.	[illegible]	1895.
Winter	2,672 601	8,251,550	136,989,047	312,608,310	1,684,078	1,046,720	3,085,634	15,881,618	107,081,460	73,450,000				
Spring	6,797,896	7,047,285												

*Monthly Review Iowa Weather and Crop Service. 6: N. 1894. Ann. Rep. 1895: 34.

According to Mr. Hyde in the Year Book of the Department of Agriculture for 1899, the crop production for the principal cereals of the United States for 1899 was as follows:

	Corn, Bushels.	Wheat, Bushels.	Oats, Bushels.	Barley, Bushels.	Rye, Bushels.
Maine	427,438	42,342	4,898,688	347,652	14,745
New Hampshire	975,546	8,789	1,047,445	115,500	13,989
Vermont	1,710,926	78,889	3,059,228	548,904	58,941
Massachusetts	1,449,504	....	459,087	50,850	133,298
Rhode Island	251,508	....	95,268	9,125	....
Connecticut	1,799,411	5,490	525,056	....	256,464
New York	15,605,069	7,005,768	45,401,688	4,082,473	2,628,609
New Jersey	9,937,894	1,789,805	2,284,648	....	1,000,765
Pennsylvania	40,255,873	20,472,928	39,148,083	170,844	3,886,080
Delaware	4,547,313	982,557	330,069	....	....
Maryland	18,562,423	10,710,966	1,676,596	....	253,378
Virginia	34,880,900	6,890,450	5,145,518	....	389,471
North Carolina	31,953,188	3,495,598	4,787,208	....	230,279
South Carolina	16,712,139	988,762	3,023,976	....	18,135
Georgia	32,494,799	2,081,285	4,291,857	....	24,880
Florida	5,093,370	....	330,454	....	....
Alabama	33,016,180	431,128	3,012,070	....	14,570
Mississippi	30,043,713	26,010	1,365,740	....	....
Louisiana	25,806,736	....	553,294	....	....
Texas	81,151,398	9,044,635	17,067,975	26,460	37,680
Arkansas	48,087,180	1,954,361	5,984,448	....	19,068
Tennessee	60,997,780	8,392,397	5,226,244	18,580	107,088
West Virginia	18,043,584	3,890,751	3,158,456	....	132,290
Kentucky	55,592,697	8,901,575	6,194,805	25,091	244,420
Ohio	99,048,816	39,998,036	32,945,976	602,490	635,980
Michigan	26,470,350	13,335,198	30,509,048	927,144	1,097,012
Indiana	141,858,594	25,361,175	34,301,948	158,300	484,628
Illinois	247,150,328	12,665,410	127,278,968	395,508	1,154,385
Wisconsin	41,686,365	11,778,289	67,687,380	7,670,650	3,078,135
Minnesota	31,171,373	68,228,781	52,688,416	8,144,195	1,112,472
Iowa	342,249,841	18,195,489	126,985,749	12,011,896	2,039,969
Missouri	162,915,064	11,398,708	21,299,250	12,960	197,428
Kansas	237,612,269	38,469,044	39,130,410	4,163,185	1,646,958
Nebraska	224,673,268	20,791,776	51,474,120	943,176	997,104
South Dakota	30,017,416	37,728,320	15,323,378	2,410,354	86,765
North Dakota	653,495	61,758,630	17,987,670	4,909,269	244,725
Montana	36,386	1,792,985	2,817,468	216,405	....
Wyoming	53,944	395,345	442,390	....	....
Nevada	....	637,006	....	....	....
Colorado	2,911,466	7,297,781	2,448,846	337,989	38,226
New Mexico	450,900	2,579,856	178,083	88,488	....
Utah	162,660	3,736,454	672,236	194,565	56,694
Washington	138,476	21,710,394	2,091,965	1,410,260	25,969
Oregon	297,416	21,949,526	5,118,670	787,916	61,779
California	1,536,975	22,748,909	1,842,787	22,239,776	647,069
Oklahoma	10,126,966	16,908,765	....	....	....
Arizona	....	342,129	....	....	....
Idaho	....	3,440,106	4,069,966	406,510	....
United States	2,078,143,933	547,303,846	796,177,713	73,381,563	23,961,741

Climatology.

Climate has such an important bearing, not only on the production of our cereals, but on the production of grasses, that a few tables should be introduced, showing the amount of precipitation for the growing months, as well as the annual rainfall. It is equally important to know the temperature for the same period. Dr. Geo. M. Chappel, of the U. S. Weather Bureau, and J. R. Sage, of the Iowa Weather and Crop Service, have kindly furnished me with the following data:

SIOUX CITY.

Precipitation—inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	3.56	3.17	1.63	2.29	5.85	1.11	23.83
1894	2.79	1.91	2.74	1.81	1.68	0.73	18.79
1895	3.20	2.15	4.95	2.63	1.54	3.91	20.29
1896	6.16	6.39	2.94	5.54	0.86	2.09	30.77
1897	4.03	1.24	2.13	2.26	2.51	0.51	20.38
1898	1.37	4.69	6.61	2.78	3.10	0.95	22.91
Averages	3.52	3.26	3.50	2.88	2.59	1.55	22.83

Mean total for the six crop months—17.30.

Temperature—degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	44.6	57.0	72.0	75.0	70.7	66.0	45.0
1894	51.6	62.4	72.0	76.0	75.2	65.7	49.2
1895	57.0	62.0	68.0	72.4	72.6	67.7	47.8
1896	52.0	64.4	70.0	72.4	71.8	58.4	41.2
1897	47.6	59.1	68.4	76.2	68.2	71.7	46.8
1898	49.6	59.5	70.9	73.3	72.5	65.2	47.8
Average	50.4	60.7	70.2	74.2	71.8	65.8	46.4

Average for the six crop months—65.5.

CRESCO.

Precipitation—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	5.95	2.79	4.14	3.85	1.20	2.08	......
1894	3.21	2.63	3.00	0.09	1.03	3.16	22.76
1895	1.69	3.39	3.83	4.37	2.52	1.69	24.38
1896	5.09	6.74	4.27	3.26	2.62	4.83	24.07
1897	2.23	0.69	6.95	2.12	4.36	3.26	25.04
1898	2.80	2.84	2.53	2.91	1.35	1.03	23.91
Averages	3.50	3.18	4.12	2.77	2.18	2.68	24.03

Mean total for the six crop months—18.43.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	40.2	52.9	68.2	71.1	67.4	60.5	....
1894	48.7	58.1	69.4	74.2	72.0	62.4	46.2
1895	51.0	58.8	66.6	69.2	70.2	65.0	43.1
1896	50.2	62.9	66.3	69.4	69.1	55.4	44.3
1897	44.8	55.8	64.8	72.1	65.0	67.2	43.5
1898	44.8	57.9	67.6	71.2	69.4	63.6	44.5
Averages	46.6	57.7	67.2	71.2	68.8	62.4	44.3

Average for the six crop months—62.3.

KEOKUK.

Precipitation.—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	5.41	4.36	2.37	2.60	1.16	3.18	27.94
1894	2.75	3.06	2.95	0.37	0.51	4.86	25.20
1895	3.38	3.45	2.61	5.46	2.28	2.67	29.42
1896	2.35	4.40	2.18	8.01	3.90	9.44	36.77
1897	3.34	1.86	5.43	6.75	0.65	0.64	33.14
1898	4.80	6.70	4.77	3.06	6.92	8.07	52 48
Averages	3.67	3.97	3.38	4.38	2.57	4.81	34.16

Mean total for the six crop months—22.78.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	49.9	59.8	73.0	78.0	72.0	69.0	49.9
1894	54.0	63 0	76.0	78.0	77.0	68.0	53.7
1895	55.1	6[illegible].6	73.0	73.8	76.7	70.7	50.8
1896	60.0	70.0	71.8	76.0	74.9	62.5	53.0
1897	51.3	61.2	72.9	78.3	72.4	74.4	52.6
1898	51.8	64.0	75.6	77.1	75.7	70.8	52.9
Averages	54.4	63.6	73.7	76.9	74.8	69.2	52.2

Average for the six crop months—68.8.

SIBLEY.

Precipitation.—Inches.

	April	May.	June.	July.	August.	September.	Annual.
1893	......	1.65	2.41	3.37	2.26	0.88	......
1894	4.13	3.59	3.34	1.01	0.97	2.57	22.47
1895	2.81	5.20	4.85	1.13	0.67	......	......
1896	5.33	5.42	3.92	3.67	4.38	6.67	38.65
1897	2.48	0.73	4.20	4.32	0.95	1.15	24.98
1898	1.44	5.42	4.99	2.69	3.06	0.67	21.63
Averages	3.24	3.67	3.95	2.70	2.05	2.39	26.93

Mean total for the six crop months—18.00.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	......	55.2	69.1	69.3	66.4	60.9	......
1894	48.1	58.6	69.8	72.6	71.4	62.6	45.8
1895	54.0	58.2	65.0	......		......	......
1896	48.8	61.8	66.6	69.2	68.6	56.0	......
1897	44.7	56.0	64.8	72.2	64.0	68.6	......
1898	46.0	56.5	68.1	70.5	67.6	62.9	44.6
Averages	48.3	57.7	67.2	70.8	67.6	62.2	45.2

Average for the six crop months—62.3.

DES MOINES.

Precipitation—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	5.61	2.84	4.69	3.55	1.60	1.33	25.64
1894	1.70	1.41	1.67	0.29	1.89	4.46	20.06
1895	3.41	2.86	5.26	3.10	3.57	3.20	26.80
1896	3.47	6.50	2.69	8.15	5.49	3.61	37.09
1897	7.37	2.31	3.15	2.88	1.77	1.56	27.07
1898	2.64	4.22	6.85	1.86	1.09	1.91	28.33
Averages	4.03	3.36	4.05	3.30	2.57	2.68	27.50

Mean total for the six crop months—19.99.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	46.0	56.9	71.4	75.5	70.0	66.2	46.7
1894	53.0	62.0	74.4	77.7	76.0	66.7	51.2
1895	55.4	62.7	70.5	72.7	73.8	69.4	49.0
1896	56.0	66.5	70.1	73.2	72.7	59.6	50.1
1897	49.4	59.7	70.0	76.4	70.4	73.7	49 6
1898	50.0	60.7	72.2	74.2	73.8	67.4	49.5
Averages	51.6	61.4	71.4	75.0	72.8	67.2	49.4

Average for the six crop months—66.6.

CEDAR RAPIDS.

Precipitation.—Inches.

	April	May.	June.	July.	August.	September.	Annual.
1893	3.89	2.79	4.89	1.98	2.47	2.85	30.67
1894	1.65	3.08	2.43	0.18	2.51	3.96	26.27
1895	2.30	2.84	2.23	3.22	1.50	3.64	23.39
1896	5.23	3.99	1.91	6.59	2.40	3.16	29.77
1897	5.97	2.10	3.96	4.35	2.62	3.78	29.34
1898	2.47	3.41	3.60	1.90	4.38	3.11	29.58
Averages	3.58	3.04	3.17	3.04	2.65	3.60	28.17

Mean total for the six crop months—19.08.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual.
1893	45.9	57.2	72.2	73.3	70.2	64.8	46.4
1894	53.2	61.8	74.4	76.1	74.7	65.3	50.8
1895	54.2	63.0	72.6	74.0	74.6	69.9	48.8
1896	59.2	69.8	73.2	74.2	78.8	59.1	50.2
1897	47.4	58.0	68.6	76.4	58.7	70.9	47.9
1898	48.8	60.8	73.2	75.4	73.3	67.3	48.7
Averages	51.4	61.8	72.4	74.9	72.6	66.2	48.8

Average for the six crop months—66.6.

CLARINDA.

Precipitation.—Inches.

	April.	May.	June.	July.	August.	September.	Annual.
1893	3.11	3.17	4.12	8.84	6.22	2.38	33.27
1894	2.06	1.37	4.02	0.41	0.23	2.53	17.96
1895	2.82	2.99	8.33	6.44	4.64	0.95	30.79
1896	3.72	7.48	2.12	6.63	2.86	2.56	33.73
1897	6.00	2.01	4.04	2.63	2.53	1.55	26.32
1898	3.70	5.15	2.99	4.49	1.16	5.74	33.49
Averages	3.57	3.70	4.27	4.91	2.94	2.62	29.26

Mean total for the six crop months—22.01.

Temperature—Degrees.

	April.	May.	June.	July.	August.	September.	Annual
1893	47.4	57.9	70.5	75 3	69.6	65.9	47.1
1894	53.3	62.1	73.5	76.3	77.6	66.4	51.0
1895	53.9	62.2	68.6	70.2	73.2	68.4	47.8
1896	54 3	63 8	68.4	73.7	73.8	61.5	49.8
1897	50.8	61 6	72.9	78.8	71.6	73.2	51.3
1898	51.8	62 2	75.0	80.2	80.6	72.6	52.4
Averages	51 9	61.6	71.5	75.8	74.4	68.0	49.9

Average for the six crop months—67.2.

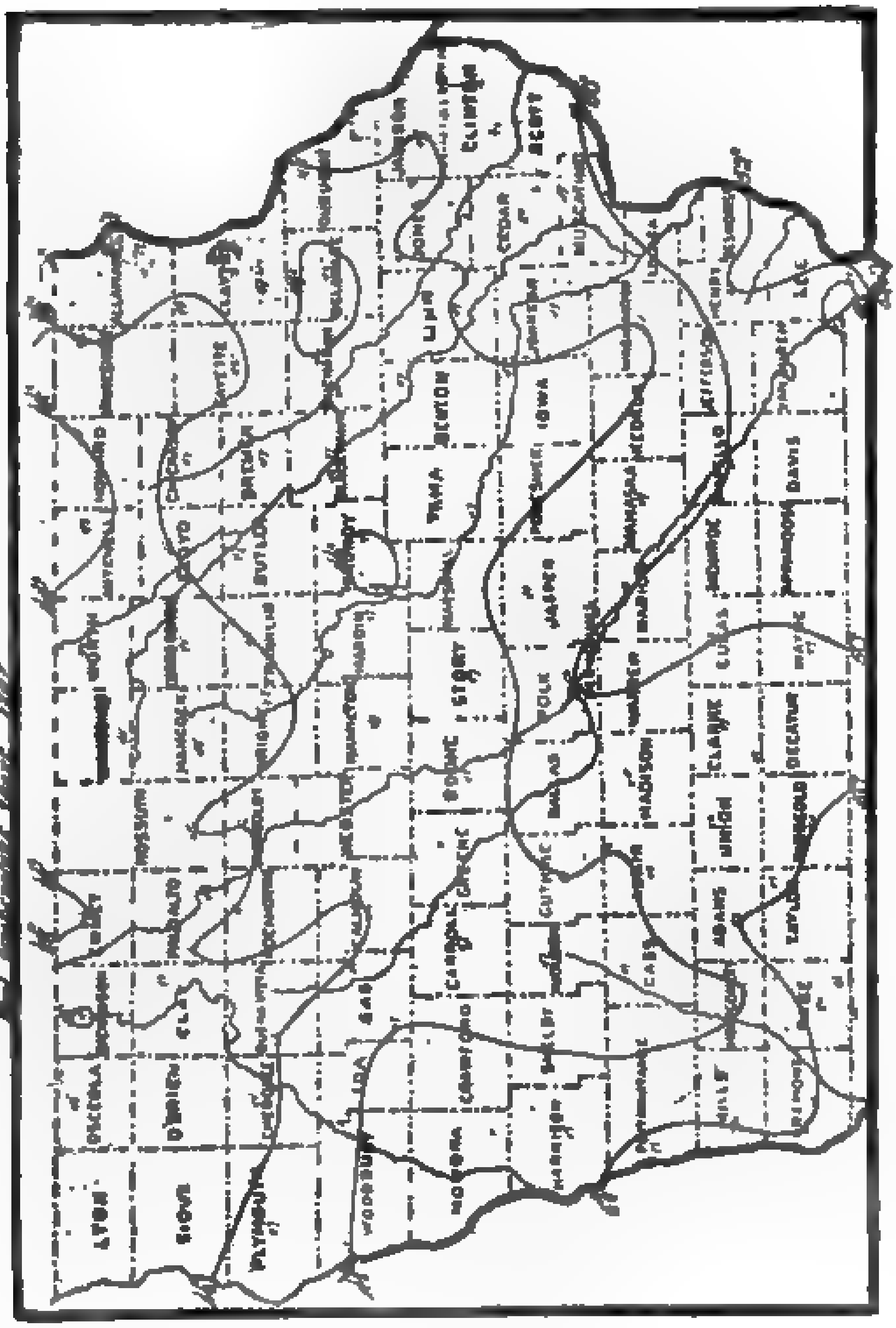

Fig. 73 A. Mean Temperature 1898 (Dr. Chappel.)

Dr. C. Hart Merriam, who has been considerably interested in the geographical distribution of animals and plants, has divided the United States with reference to cereal production and the geographical distribution of plants into boreal, transition, upper austral, lower austral, gulf strip of lower austral and tropical. The tropical, of course, is confined to the southern portion of Florida, reaching Texas on its southwestern boundary for only a short distance, on the western coast of America, up the gulf of lower California to Arizona. The boreal does not strike the state of Iowa but lies chiefly to the north of the United States and extends down through the mountain regions of the western coast and the Rocky mountains. It is of some extent also along the Atlantic coast. The transition zone occupies an area chiefly through northern Wisconsin, Minnesota, Michigan, New York, Massachusetts, Maine and scattered areas in the Rocky mountains and in the Pacific coast region. This zone extends into northern Iowa. The greater part of the state of Iowa lies in what is known as the upper austral. This includes most of the prairie states, including some area in the Rocky mountain states and some of the Pacific coast. It embraces a portion of Ohio, West Virginia and a small area from Virginia to Alabama, thence northwest through Tennessee and Kentucky, northern Arkansas and a portion of Oklahoma. The lower austral occurs along the Atlantic coast from Virginia southwest to Mexico, extending as far north as southern Kansas, western Kentucky and Tennessee and only a very limited area in southern Missouri. The gulf strip of the lower austral is chiefly confined to a small strip along the gulf coast including the greater part of Florida.

Prof. C. S. Plumb, under the direction of Dr. C. Hart Merriam, has gathered together some facts on the distribution of the cereals. It may be of interest to state what he has found with reference to some of our chief cereals. The flint corns, such as Longfellow and King Phillip occur in the transition and upper edge of the upper austral. The dent corns like Hickory king, Bloody butcher, St. Charles white, occur in the upper austral; Hickory king in the upper austral and upper part of lower austral; Mosbey's prolific, lower austral; pride of the north, transition; Stowell's evergreen, upper austral; pop, all varieties, upper austral; winter wheat, Clawson, transition and upper austral; Fullcaster, Turkey red, upper austral; spring wheat, Ladoga, Saskatchewan, fife, transition;

Sonora, upper and lower austral; oats, of the open panicle type, American banner, transition; Welcome and Lincoln, transition and upper Austral; red rust proof, upper and lower Austral; oats with closed panicle, white Russian, transition zone; black Tartarian, transition.

Fig. 72. South American corn (*Zea mays*). Climate and the growth of maize. This failed to mature in Iowa. Had a large number of nodal roots.

Maize.—Harshberger*, who has studied the various phases of maize, presents an interesting meteorological table of various points in Mexico for the months of April, May, June, July, August, September and October, 1889. He introduced evidence determining that it originated in Mexico, probable near Guadaljara, Leon and Pueblo. Leon is 5,400 feet above the level of

*Maize: l. c. Contr. Bot. Lab. U. of Penn. 1: 75-202. pl. 14-17. 1893.

the sea, it is therefore a highland plant. Its original home was south of the 22° north latitude.

In regard to the climate Brewer* states: "That the bulk of corn is grown not as is generally supposed, in the warmer parts of the United States, but in the states Illinois, Iowa, Missouri and Indiana 40.8 per cent of the entire crop grows where the mean annual temperature is between 45° and 60° F. Below an annual temperature of 45° F. the product falls off very rapidly, while above 50° F. it falls off very slowly. The distribution of the crop depends on certain climatic conditions. The mean annual temperature is of less importance, and it is very important that the rain fall should be evenly distributed. "The table of the distribution of the crop according to elevation shows that over 50 per cent is grown at an elevation of between 500 and 1,500 feet, only 4.4 per cent above that, and only about an eighth of the crop is grown nearer the sea level than 500 feet."

Corn needs hot weather, plenty of sunshine and a sufficient amount of rainfall. In 1894 the average yield for Iowa was twelve bushels per acre, a little over one-third of an average crop. Acreage planted 6,738,970; total yield 80,867,640 bushels. About 60 per cent was cut for fodder. It is interesting to note the fluctuation in the crop reports for that year. The figures were in June, 101 per cent; July, 107 per cent; August, 40 per cent, and September, 36 per cent.

Mr. C. F. Spring, under the writer's direction, has made an estimate of the number of bushels per acre in the north half of the state, and the south half. The average for the north half of the state for the year was thirty-six bushels per acre; for the south half, thirty-eight.

Every portion of the state of Iowa is adapted to the growing of corn, and from a climatic standpoint corn is one of the most interesting of cultivated plants. It is wonderfully flexible in its nature, and this flexibility makes it possible to cultivate it over a wide range of latitude. Simmonds† says: "Its flexibility of organization makes it very easy of adaptation to climate and soil." It is now cultivated on the western continent from Patagonia to Canada, an extent of territory north and south of over 7,000 miles. The many varieties that have been produced under these very different conditions show great vari-

*Cereal production. U. S. Tenth Census Rep 3:100.

†Tropical Agrl. 295.

ations, not only in the texture of the grain but in the fruit, leaf, stalk and ear. All of the varieties are marked by certain peculiarities.

Wheat.—This important cereal assumes important changes under different climatic conditions, but less so than corn. Major Hallet* has shown that some varieties are quite constant. Metzger† states that a variety of wheat which was quite constant in Spain, assumed its proper characters only during hot summers. Another variety, when cultivated in Germany, became more constant only after twenty-five years of cultivation.

The most northern extension of wheat is obtained in Norway, according to Schuebler‡, at 64° north latitude. Schuebler further states that under favorable conditions summer wheat may ripen as far north as 68° 28′. At Skibotten this cereal was sown May 9, 1870, germinated on the 23d, and ripened on the 30th of August, therefore requiring 113 days. The mean temperature for May was 41.2° F.; June, 55.6° F.; July, 55.6° F.; August, 55.1° F.

Winter wheat does not mature because of the long period that the ground is covered with snow. The lowest southern latitude at which wheat is grown is at Chili in the Chilian colony, Punta Arenas Magellanes. The chief zone in which wheat occurs is in the north and south temperate zones. In tropical regions the temperature is too high to allow the proper development of wheat. This is shown very nicely in the tables presented on a preceding page. In regard to the United States the success of the culture of wheat is very materially affected by the long warm and hot months. Thus the southern United States is not a wheat growing country because of the rankness and vigor of the vegetation. This causes an undue amount of rust. Where the culture of wheat is successful in the warm regions, especially the southern parts of the tropical regions, its culture must be carried on during the winter months. According to Royle§, it succeeds best from October to March, and in the sub-tropical zone from November to May. Wallace‖ in his work on India states that it flourishes best where the supply of sunlight is abundant, yet it is in regions of moderate

*Gardners' Chronicle. Darwin. Animals and plants. 1: 382.

†Getreidearten 66. 91. 93. 116. 117.

‡Die Pflanzenwelt Norwegens. 75.

§Royle. Illustr. Bot. of the Himalaya. 418.

‖India in 1887. 247.

temperature and moderate rainfall, but we find it grown to the greatest advantage in that part of India where, at least during the winter months, the climatic conditions of the summer of Europe are most nearly approached. Definite limitation of area cannot be made since the region is not itself sharply defined.

A study of the tables prepared by Professor Brewer shows that the greatest production of wheat occurs where the mean annual temperature is 50° and 55° F. The ideal climate for wheat is one of mild winters, and some of the most noted wheat regions of the world are where snow and frozen ground are unknown or very rare although most of the wheat of the world grows in regions of cold winters. Rainfall, also, has a marked influence on the amount of wheat production. Twenty-eight per cent of the crop of the United States grows with an annual rainfall of between 40 and 45 inches, 62.7 per cent where it is between 35 and 50 inches and 92.4 per cent where the annual rainfall is above 25 inches, although there are some exceptions, as in California where the mean annual rainfall is less than 25 inches.

Wheat ripens successfully at the following altitudes: Norway, 300 m.; on the southern exposure of the Alps, 1,264 m., and Thibet, 4,549 m.

The quality of the grain produced in any locality is dependent upon several conditions; namely, climate, soil and cultivation. It is said by Frank T. Shutt that certain Russian wheats, like Ladoga,* cultivated in the northwest territory has been greatly improved since its growth in the Canadian provinces. There is a well-marked increase in the amount of albuminoids. The main difference between the hard and soft wheat is that the hard wheats contain a greater amount of albuminoids while the soft wheats contain a greater amount of starch.

Koernicke and Werner† state that the colder regions of the temperate zone are more favorable for the soft wheats. These are especially characterized by the low contents of albuminoids. These varieties where grown in dry and warmer countries are characterized by an increase in albuminoids. Only certain portions of Iowa are adapted to the growing of spring wheat. The average number of bushels per acre in northern Iowa is seventeen; in the south half of the state Mr. Spring estimates

*Saunders Bull. Canada Cent. Exp. Farm 12: 1896.
†Handbuch 2: 483.

the yield per acre at only fourteen bushels. Winter wheat shows just the opposite, the yield in the north half of the state was only seventeen bushels per acre, the south half, nineteen.

Rye.—Rye in a general way covers the same territory that wheat does. According to Koernicke and Werner* the southern extension is at Punta Arenas Magellanes, 50° south latitude. In Switzerland it matures between 1,700 m. and 1,900 m. In the United States the successful cultivation of rye extends further southward than that of wheat and oats. In regard to its culture in the United States it may be said that the chief region of its cultivation is north of the Ohio river and west to central Nebraska, although it is successful further south than wheat, especially in the states of Texas, Louisiana and Mississippi. Professor Brewer† says concerning its culture: "During the whole colonial period, and, indeed, far into the present century, it was the common ingredient of bread for a great many families in this country. Wheat never flourished well in portions of New England, and the same may be said in a lesser degree of parts of the middle states and of a belt of land extending southward along the Appalachian mountains, while over the whole of this region rye flourished reasonably well." In this state the same conditions hold as to wheat, sixteen bushels per acre in the south half and nineteen for the north half.

"Before the days of railroad transportation, and especially before the opening of the Erie canal, rye bread was the common bread among a large portion of the population of the whole region indicated, in many places, particularly in New England, rye being usually mixed with corn for bread, and 'Rye and Indian' was a familiar term in most households east of the Catskills and north of the Delaware. A similar bread of maize and rye is still common bread of Portugal, the relative proportions of each varying with the year, a good year for rye being usually a poor one for corn, and the composition of the bread varying accordingly."

The distribution and importance of rye in Europe is much greater than in the United States, but in a very general way it covers the same area as wheat does. The vegetative period is about 125 days for summer rye, with a mean temperature of 54°.

*Handbuch 2: 879.

†Cereal Production. Tenth Census Rep. 3.

Barley.—Of the cereals, with the exception of corn and sorghum, barley is of a wider distribution than any of the others. The white four-rowed barley (*Hordeum tetrastichum pallidum*) extends further northward than any other form, 70°. Its period of vegetation has been much shortened and it is less sensitive to the unfavorable weather and night frosts in this high northern latitude. According to Dr. Unger this barley is sown in Umea on the 30th of May, and is harvested on the 25th of August, the vegetative period being eighty-five to ninety days. The average yield per acre in Iowa for the north half of the state is thirty-one; for the south half, twenty-eight.

Oats.—The distribution of oats is not so extensive as that of barley or rye. In the humid temperate regions it does not succeed. Oat culture is not extensive in the warm, dry climates, especially with an intense heat. Its vegetative period is long and for that reason it is not grown so far north as barley. The vegetative period varies between eighty-eight and 150 days. The units of heat required to develop different varieties is between 1,404.37, for certain varieties in Germany and 2,060 for certain varieties in Paris. These figures are according to Dr. Wittmack.*

The place of the greatest production of oats is in the Mississippi valley, which grows 63.1 of the whole crop. The reasons for this are not so much the climate as the peculiar topographic features. Ninety-one per cent of the crop is grown between an altitude of 100 and 105 feet. Mr. Spring's studies show that in Iowa the average yield per acre for the north half of the state was thirty-nine bushels; for the south half, thirty-one.

Sorghum.—This is the chief cereal crop in tropical and subtropical Africa, and has also spread over parts of Arabia, Asia Minor, India, China and Japan and is found also to some extent in southern Europe where it succeeds admirably. The dry climate of our own country, especially in Kansas and Nebraska, is admirably suited to sorghum cultivation. In Europe, on the steppes of Russia, it scarcely reaches beyond 48° north latitude, according to Koernicke. Prof. Thos. A. Williams says concerning its growth in the United States†: "The sweet sorghums are successfully grown in nearly every state and territory in the union, the only exception being some of the colder New England states and those in the northwest which include

*Koernicke-Werner. Handbuch 2: 751.

†Sorghum as a forage crop. Farmers Bull. Of. Exp. Stat. U. S. Dept. of Agrl. 50.

the higher altitudes of the Rocky mountains and other ranges. In most localities south of Pennsylvania, Minnesota and Oregon, two or more crops may be harvested in a single season."

Rice.—The early varieties of rice mature in from 100 to 120 days. the late varietes from 150 to 200 days. They require a mean temperature of 55° F., summer varieties of 71° to 89° F., being an average mean of 68° F. Rice culture is most successful in tropical and sub-tropical regions, although it has succeeded as far north as 38° north latitude in Illinois, but its culture is nearly abandoned in that state. Its general successful commercial culture in the United States does not extend much beyond 34° along the Atlantic coast, and then again extensively along the Gulf coast. Koernicke states that its latitude in Europe is 45°. Its general culture in Asia occurs in Corea, Japan and China. Simmonds says: "One of the most extensively diffused and useful of grain crops, and supporting the greatest number of the human race, is rice. It occupies, in fact, the same place in most tropical regions that wheat does in the warmer parts of Europe, and oats and rye in those more to the north. It is raised in immense quantities in India, China, Java and most eastern countries, in parts of the West Indies, Central America and the United States, and in some of the southern countries of Europe. The chief food of perhaps one-third of the human race, it affords the advantages attending wheat, maize and other grains, while it is susceptible of cultivation on land too low and moist for the production of other useful plants."

Grasses in Medicine.

Quack grass.—But few of the grasses are used in medicine. One of the best known of the grasses used in medicine is quack grass (*Agropyron repens*). The root is taken in the form of a decoction and is a useful remedy in suppression of urine and vesical calculus. The drug is still much used in France, where it is used for the discharge of mucus from the bladder.

Lemon grass.—The lemon grass oil or citronella oil is derived from several species of the genus Andropogon. The *A. Nardus* is a native of Ceylon and Hindoostan. The *A. citratus* or lemon grass oil of verbena is likewise cultivated in Ceylon and Singapore and is native to the same general region. Another species, *A. schoenanthus*, is native to northern and central

India, and by distillation yields the Rusa oil. These aromatic oils have been known since early in the eighteenth century, and have become commercial products since the early part of this century. It is used principally for rheumatism, and Rusa is said to stimulate the growth of hair. The lemon grass oils are used most extensively in America by soap makers and perfumers. In India cattle are said to be very fond of the fragrant Andropogon and the flesh and milk become strongly flavored with its strong aroma.

Andropogon.—A related species of Andropogon, *A. laniger*, is used in India for cholera. The roots have a very strong odor analagous to myrrh. The roots of *A. muricatus*, native to southern India and Bengal, were anciently much used by the Brahmins, where it is known as cuscus grass. The roots are much used for making screens known as tatties, and when wetted give off an agreeable odor.

Cumarin.—Several of our grasses are known to give off an odorous product, e. g. cumarin, and this is identical with that found in the tonka bean (*Dipterix odorata*). Two grasses producing cumarin are found in this state, namely, sweet vernal grass (*Anthoxanthum Puelli*) and our northern vanilla grass (*Hierochloe borealis*).

Phragmites and Arundo—An infusion of the roots of *Phragmites vulgaris* is used as a diuretic. The rhizomes of *Arundo Donax* are also used for the same purpose.

Paspalum and Coix.—The *Paspalum notatum* Flugge is used for g·norrhœa. The *Coix lachryma* is used as a diuretic and to combat inflammatory affections of the respiratory organ. In China it is extensively cultivated for a similar purpose. It is also used as a diuretic according to Gomez de la Maza.* The capsules are used by followers of the Roman Catholic faith for rosaries.

Hordeum.—Mention should be made also of the use of barley (*Hordeum sativum*) in medicine. This anciently cultivated plant has been used in medicine for a long time. The so-called pot or hulled barley is only partially deprived of its husks. In pearl barley all the integuments are removed, and this is the barley that finds a place in the Pharmacopoeia. Barley is used especially for the making of drinks for sick in febrile, in pulmonary and urinary disorders.

Sugar cane—*Saccharum officinarum* also largely enters into medicines. It is known by the pharmaceutical name of Sac-

*Essayo farmacofitologia Cubana 8.

charum. Cane sugar has a chemical composition of $C_{12} H_{22} O_{11}$. Its medical use when in solution is almost exclusively lenitive, but in powder it is a stimulant, and is employed to diminish dryness of the mouth and fauces, to stop irritation and mitigate cough. It is said also to have a diuretic effect. Used in a moderate quantity it promotes digestion and stops nervous excitment. It is said also to be a very efficient remedy for apathæ of the mouth, and in granular eyelids. It is also said

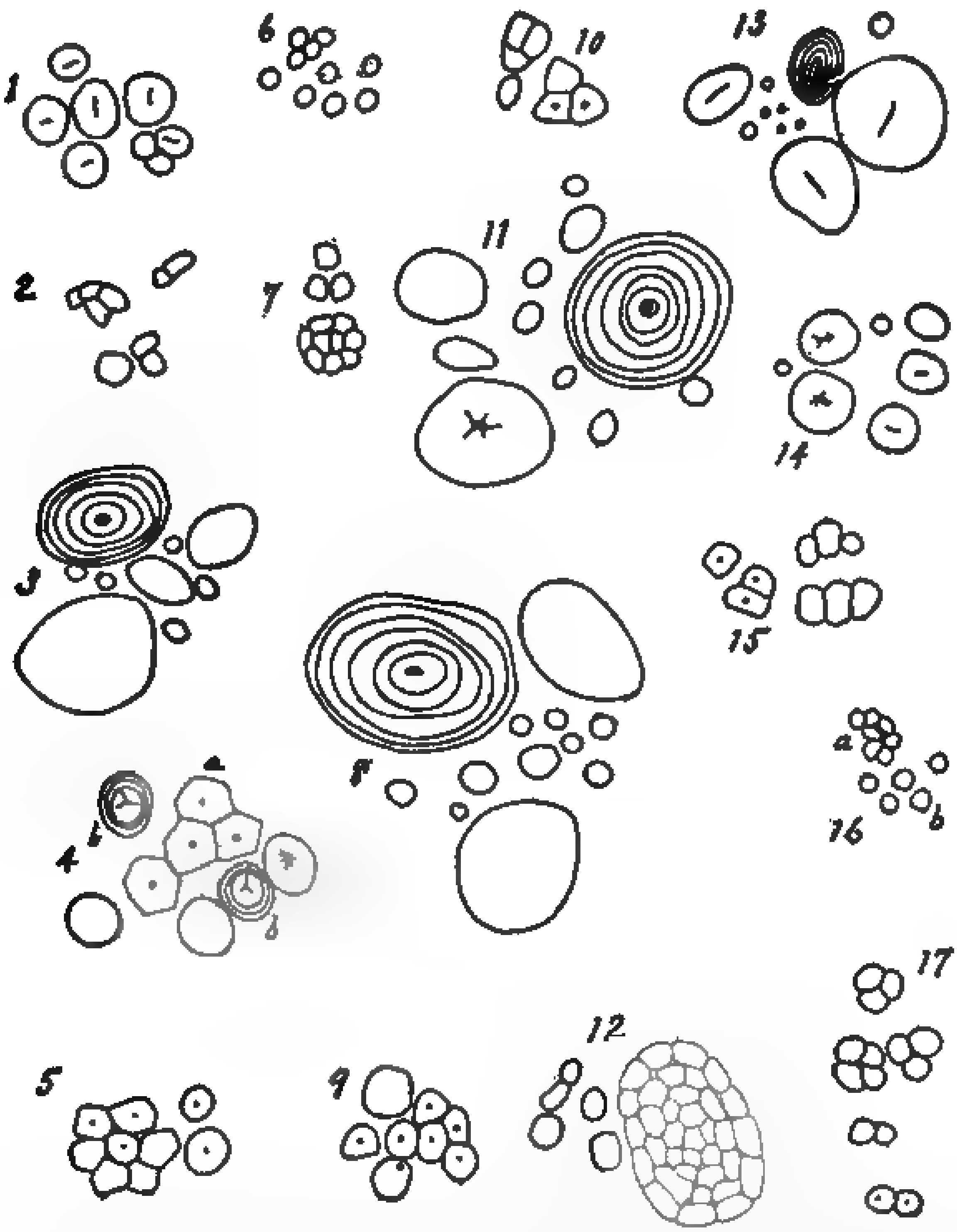

Fig. 74. Amylum. Various forms of starches from grass endosperm: 1, sorghum; 2, rice; 3, wheat; 4, maize; 5, Italian millet; 6, *Panicum miliaceum*; 7, *Eragrostis abyssinica*; 8, wh at more magnified than 3; 9, barnyard grass; 10, *Panicum sanguinale*; 11, rye; 12, oats; 13, barley; 14, Jerusalem corn; 15, buckwheat; 16, manna grass; 17, *Eleusine coracana*.

to be valuable in chronic laryngitis when inhaled by a sudden aspiration.

Refined sugar is extensively employed in making lectuaries and lozenges. Not only does it prevent the unpleasant taste but acts as a preservative.

Amylum.—Amylum or the starches are of universal distribution in the endosperm of grasses but the only starches used in a medicinal way are those of wheat, corn, rice, rye and oats. These starches differ in their structural peculiarities, but all have the same chemical composition. The drug known as Catchu is frequently sold in India, and contains the flour of Rage (*Eleusine coracana*). In India it is made into tablets and lozenges. Its principal medicinal qualities do not reside in the starch of the grasses but is due to the stringent qualities of the cutch.

Most alcoholic stimulants are derived by a process of fermentation of the starches contained in rye, barley, wheat, corn, and rice. For ordinary malt liquors barley is largely used and also starches of corn and rice. The products of wheat, corn and rye are largely used for the various brands of whiskies.

Glucose.—Glucose, having the chemical composition of $C_6 H_{12} O_6$ though existing naturally in grapes and a large number of fruits is usually prepared by the action of hydrochloric or sulphuric acid upon starch, the term glucose being applied to the syrupy product made by this process and the term grape sugar to the solid product from the same source.

Maize.—The stigmas of corn silk are used in medicine under the name of Mayd's stigmata. They are diuretic and lithontriptic. An infusion of corn leaves is sometimes used as an anti febrile, but its action is said to be unreliable.*

*Harshberger (Contr. Bot. Lab. Uni. Penn. 1: 185) quotes from an article in the Am. Jour. of Phar 5: 315.

Sugar Producing Grasses.

ROBERT COMBS.

The grasses containing sugar or sucrose (C, H, O_{11}) are few, there being but three species that are known to contain it to any great extent. These species are corn or maize (*Zea mays*, L.), sorghum (*Andrорogon sorghum*, Brot.) and sugar cane (*Saccharum officinarum*, L.). These plants all have stored up in the pith cells of the internodes of the culms a greater or less quan ity of sucrose, which quantity varies greatly according to the age of the culm and the part used.

Corn.—Experiments and analysis made by Prof. Peter Collier* and others show that, though at its maximum stage, about August 20th, corn contains a goodly per cent (about 12 to 14 per cent) of sucrose, its period is of such short duration (about ten days or less) and the quantity before and after the maximum is so small that it cannot be economically used as a commercial source of sugar. The kernel, however, is used to a great extent as a source of glucose, the latter being obtained by the action of sulphuric acid on the starch.

Sorghum.—Certain varieties of this grass have been clearly shown to contain sucrose, varying from 13 to 18 per cent, and holding this content from four to six weeks, or even longer. The United States Department of Agriculture† has made almost continuous experiments and investigations along the line of selecting and improving varieties, and in the matter of processes of manufacturing sugar from sorghum from 1879 to 1893.

Experiment stations were established in various parts of the United States‡, and especially in different parts of Kansas, where at one time (1889) there were nine.

The plant was much improved in sugar content and much improvement was made in the process of manufacture, but since the removal of the sugar bounty (1893) the industry has entirely collapsed.

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*Report U. S. Dept. of Agrl. 1881-82: 452 *pl. 14-16.*
†Reps. U. S. Dept. Agrl. 1880-87:
‡Bull. U. S. Dept. Agrl. Div. Chem 2: 6: 8: 14: 17: 18: 20: 26: 29: 34: 37: 40.

Sorghum cane has been used for many years for the manufacture of a kind of syrup known in commerce as "sorghum molasses." It is made by expressing the juice from the trimmed stalks by means of a mill or roller pressure, straining and clarifying, sometimes by the addition of a small quantity of freshly slacked quicklime, and heating to boiling, skimming and settling, but usually without the addition of lime, although in this way it produces an inferior product.

It would seem that the process of manufacture must be at fault at some point and that point is in the clarification of the juice. The gums or "solids not sugar," impurities of the juice are of such a character that they cannot be removed by any known process of clarification without sufficient facility and economy to enable the sucrose content to be easily crystallized; therefore the financial failure of the industry when put upon its own feet and unassisted by government bounties.

Sugar cane.—Commercial sugar was obtained only from sugar cane until the early part of the present century, when sugar beets were discovered to be an available source. The Chinese* claim to have manufactured sugar from cane for over 3,000 years. They most probably obtained it either in Cochin-China or Bengal, where all evidence points to the plant having been native. Many Greek and Roman writers speak of either sugar or cane, or both.

The best of the more recent accounts on the production of sugar may be obtained from Stubbs†. Simmonds‡ in his work on Tropical Agriculture treats the subject very fully.

Other Uses of Grasses.

Grasses are widely used for other purposes. It is impossible for us in this connection to give all the different uses to which grasses are put. The *Panicum junceum* is used in Argentine Republic as a substitute for soap. Straw paper is made out of straw of several cereals. A great deal of other straw is also manufactured into paper of various kinds, and this is a subject of considerable commercial importance. Paper is made not only from rye and wheat but also from maize, and the time will come when the manufacture of paper from maize will assume much greater importance than it does at present. Dr. Harshberger says of the maize: "Maize seems to be the best adapted

*Wray. The practical sugar plants. 1848. Stubbs Sugar cane. 1.
†Stubbs Sugar cane. 1.
‡Tropical Agriculture. 128.

to the purpose. In the last century two maize-straw paper manufactories were in existence in Italy. The paper produced was not of a satisfactory quality, the cost was too great, and the manufacture forthwith stopped. The chief expense was found in the transportation of the crude material to the seat of operations. All the fibre and gluten wastes can be used in the manufacture of paper. The catalogues of the Austrian exhibition at London in 1862 in German, French and English, consists of such paper." At the present time the manufacture of paper from maize in Vienna is an extensive operation. The paper has a yellowish tint and is, therefore, very restful to the eyes. Paper of Indian corn requires very little sizing; it bleaches well and is of greater strength than rag paper, and no machinery is necessary for tearing up the leaves.

Crookes and Fischer state that "among the straw species appears the maize (Indian corn) from the fibre of which a paper is made that for purity and whiteness cannot be equalled. The inner bark of the bamboo affords a very fine paper, yielding the most delicate impressions from copper-plate, and this paper was originally called India-proof. Paper is also made from *Andropogon sorghum*. A very fine fibre is also made from Esparto grass (*Stipa tenacissima*).*

Many other grasses are adapted for fibre paper purposes and several grasses produce fibre of fine quality.

In Labrador the *Elymus arenarius* is employed for the manufacture of table mats and baskets. Bamboo (*Bambusa arundinacea*) is used for the purpose of making paper stock and the canes are also split and shredded and afterwards wrought into various forms. The Marram grass, *Ammophilia arenaria*, is used in northern England for the making of table mats and baskets and also for agricultural tie bands. For a valuable paper on the subject of fibre producing plants, the one prepared by Charles Richards Dodge, "A Descriptive Catalogue of Useful Fibre Plants of the World,"† is recommended.

The Hopi Indians use *Hilaria jamesii*. They make from the stout fibre of this plant coiled trays. The strong fibre of *Hierochloe borealis* according to Dr. Havard‡ is used by the Penobscot Indians for the making of baskets and pretty fancy work. Its long radical leaves become strongly involute in

*For an account of the making of paper see Man. of Chem. Tech. by Rudolph Von Wagner. English translation. Crookes and Fischer. 853: 1892.

†U. S. Dept. Agrl. Fiber Inves. 9.

‡Garden and Forest. 3: 619.

drying, forming flexible threads which are braided into fine strips and these are woven into baskets and other pretty fancy work. He has also found braids of this grass in the camp of the Crow Indians on the Yellowstone. The delicate and lasting fragrance of the dried leaves gives this grass additional value.

Maize husks are used extensively in the United States for upholstering purposes and for the manufacture of matresses and for similar uses. Horse collars are made of the husks or "shucks" in the south; door mats are also made in some of the northern states, these being very serviceable. Mr. Dodge says the husks are also employed in the manufacture of chip hats in Florida. These, when properly trimmed are both stylish and pretty.

The corn pith cellulose is employed as a packing material in the cofferdams in connection with the armour plating of United States war vessels. The corn pith is suitably cleaned and pressed into blocks when it is ready for use.

An excellent account of the use of corn pith cellulose and other productions of corn may be found in a recent nnmber of the Orange Judd Farmer.* This journal summarizes the various uses to which the products made from corn stalks may be put:

"1. Cellulose for packing cofferdams of battleships, this preventing them from sinking when pierced by balls or shells.

"2. Pyroxylin varnish, a liquid form of cellulose, the uses of which are practically unlimited.

"3. Cellulose used for nitrating purposes for making smokeless powder and other high explosives, for both small and great arms, as well as purposes for which dynamite or all other explosives are required in various forms and degrees of strength.

"4. Cellulose for packing, it being the most non-conductor known against heat or electricity, jars or blows.

"5. Paper pulp and various forms of paper made therefrom, both alone and mixed with other grades of paper stock.

"6. Stock food made from fine ground outer shells or shives of corn stalks, and also from the nodes or joints. The leaves and tassels also furnish a shredded or baled fodder.

"7. Mixed feed for stock, containing fine ground shells of shives as a base, and in addition thereto various nitrogenous

*27: 363.

meals and concentrated food substances, or b'ood, molasses, distillery and glucose refuse, sugar beet pulp, apple pomace and other by-produc's.

"8. Poultry foods of two types, namely—type 1, containing a dominant nitrogenous factor for laying hens, and No. 2, containing a dominant carbohydrate factor for fattening purposes."

This manufacture is carried on extensively by the Marsden Co., of Philadelphia, in Owensboro, Ky.

The straw of several varieties of wheat is used for the manufacture of braids or straw plait. The finest of these come from Italy, thus the celebrated Tuscan plait comes from Florence and is produced from a variety of wheat cultivated especially for the straw and without regard to the grain. The industry is carried on extensively also in parts of China. The straw of rye (*Secale cereale*) is likewise used for the making of hats. An interesting account of its use in this connection will be found in Mr. Dodge's paper on "The Useful Fibre Plants of the World."

Brooms.

Another important use of grasses is for the manufacture of brooms. The plant usually used for this purpose is broom corn, *Andropogon sorghum*. The cultivation of broom corn for the manufacture of brooms is an extensive industry in Ohio, Indiana, Illinois, Iowa and Kansas. Good crops may be obtained with proper attention and care on any clean, fertile soil. The seed is planted about the same time that corn is. The soil should be well tilled and in excellent condition; the weeds must be kept down to get the most remunerative crop. The brush must be cut before the seed is fully formed.

Soil Binders.

Grasses are extensively used as sand and soil binders. These grasses are especially important along the sea shores where the tides and waves are a constant menace to the land and dwellings situated in proximity to the sea. "The digging out and undermining by swift currents, the beating of the waves on lake and ocean shores and the perpetual shifting about of loose sands by the waves and winds, cost our country many millions of dollars annually," says F. Lamson-Scribner in his paper on grasses as sand and soil binders.* The sand

*Year book U. S. Dept. Agrl. 1894: 421.

or soil binding grasses have strong root stocks or rhizomes. There are two kinds of these soil binders. *First.*—The coarser kinds which are exposed to the most severe action of the winds and waves. These have their rhizomes deeply buried in the sand. *Second*—Grasses with prostrate stems that creep over the surface of the sand and produce at frequent intervals long fibrous roots. Some of the more important of the sand binders are Marram grass, *Ammophia arenaria*, the *Elymus arenarius*. Of the many other grasses which aid in holding the soil, mention may be made of the rolling spinifex (*Spinifex hirsutus*), Louisiana grass (*Paspalum compressum*), and sand grass (*Calamovilfa longifola*). The latter species is especially valuable in many sections of this state where it retains the loose sandy soil along some our streams. The *Spartina cynosuroides* is a valuable grass in holding the alluvial soil of the Missouri river bottom in position.

Oil.

Maize oil is obtained from the embryos of corn. Dr. Harshberger* says: "The oil is not obtained by direct expression, but the grain is malted, and the germ is separated by careful crushing and winnowing. The germs are then submitted to hydraulic pressure, and yield 15 per cent oil, and a press cake rich in albumen, containing 4 to 5 per cent oil. Maize oil is of a pale golden-yellow color, and has a peculiarly agreeable taste and odor. It is a thick liquid, and has a specific gravity of .9215 at 59° F. It consists of olein, stearin, palmitin, and contains some volatile oil. It solidifies to quite a solid mass at 10° C. (14° F.)."

It is one of the common by-products in the manufacture of glucose from the embryo of corn. It is an excellent oil for salad purposes and is also a possible adulterant of olive oil and used in the manufacture of soap.

Fuel.

In many of the western states the cobs of corn are used for fuel purposes, and Dr. Harshberger states that three tons of corn cobs equal one ton of hard coal for fuel purposes. It is hard to estimate the value of corn cobs as a fuel. F. N. Fowler who has charge of the Lockwood elevator, one of the largest elevators along the C. & N. W. railroad in central Iowa, states that it is impossible to make an estimate of the total value of

*lc. 187.

the corn cob for fuel purposes in this state. Mr. Fowler states that while corn cobs at 50 cents a load are good for combustible purposes, they are not so cheap as slack at $1.10 a ton. Fifteen loads are equal to a ton of hard coal. Burning cobs are extremely hard on the fire brick. It should be stated that in addition to its value for fuel purposes, a fine quality of potash may be obtained from the ash of burnt cobs.

The Poisonous Effects of Grasses.

Darnel.—It is a well known fact that a number of grasses are poisonous. It was well recognized by the ancients that darnel (*Lolium temulentum*) is poisonous, for it is written: "But while men slept, his enemies came and sowed tares among the wheat."*

Darnel, when ground up with wheat and made into flour, is said to produce poisonous effects on the system, such as headache and drowsiness. This poisonous property is said to reside in a narcotic principle, Loliim, and according to Hackel "causes eruptions, trembling and confusion of sight in man and flesh-eating animals, and very strongly in rabbits, but it does not effect swine, horned cattle or ducks." Lindley† states that the grain is of evil report for intoxication in man, beast, birds, and bringing on fatal convulsions. Haller speaks of them as communicating these properties to beer. It acts as a narcotic acid poison. Darnel meal was formerly recommended as a sedative poultice. In Taylor's‡ work on poisons, the statement is made that the seeds, whether taken in powder or in decoctions, have a local action on the alimentary canal and a remote action on the brain and nervous system. He states further that no instance is reported of its causing fatal injuries to man, and as much as three ounces of a paste of the seeds have been given to a dog without causing death. Then he goes on to cite the experience of Dr. Kingsley, in which several families, including about thirty persons, suffered severely from the effects of bread containing the flour of darnel seed. These persons had staggered about as though intoxicated. It is claimed by some investigators that this plant is not poisonous. One writer claims to have made bread with

*Matthew 13: 25-30. John Smith, Bible Plants, in commenting on the above passage, states that it is not the tares or a plant commonly called tares (*Vicia sativa*), but the above grass.

†Flora Medica. London. 609.

‡On poisons in relation to medical jurisprudence and medicine. 653. *f.* 65. 1875. (3d E) Philadelphia.

flour said to contain considerable quantity of the darnel, which was eaten without any injurious effects. There are other grasses which have a similar narcotic effect. Quite recently it has been claimed by several European investigators, notably Guerin* and Hanausek,† that the fruit of *Lolium temulentum* contains a poisonous fungus. Guerin states that the hyphae of a fungus constantly occurs in the nucellus of the seed and the layer of the caryopsis lying between the aleurone layer and the hypha portion of the wall. He also thinks that the toxic action of the Loliums is due to this particular fungus hypha. These fungus threads have not been found in *L. italicum* and but once in *L. perenne*. The fungus is allied to *Endoconidium temulentum*. The fungus lives symbiotically in the maturing grain and is therefore not a parasite. Nestler,‡ who made an examination of *L. perenne*, *L. multiflorum*, *L. remotum* and *L. festucaceum*, found nothing comparable to the fungus mycelium which occurred in *L. temulentum*. He also succeeded in demonstrating the presence of the mycelium of the fungus as indicated by Guerin. According to Nestler the *Fusarium roseum* is identical with the fungus occurring in *L. temulentum* found by Guerin.

Sleepy grass.—In the west a species of grass has received the common appellation of sleepy grass. It has long been regarded by range people as poisonous. Dr. Palmer, who found this grass in Coahuila, New Mexico, observed that it was poisonous to cattle, horses and sheep, causing them temporary sleepiness. Later Dr. Havard§ states that in 1888 he received from Dr. M. E. Taylor, of Stanton, N. M., a grass with the following statement: Hereabouts grows a grass—the eating of which by horses will, within a few hours, produce profound sleepiness or stupor, lasting twenty-four or forty-eight hours, when the animals rally and give no evidence of bad effects. It is known among cowboys as "sleepy grass" and dreaded by them on their "round ups" as their horses are liable to eat it and cannot then be kept up with the herds. The tradition is that horses that have once eaten of it will not touch it again. To quote from Dr. Havard, "From the same gentleman I received a letter in 1890, in which he says: 'Since I corresponded with Dr. Taylor it has been brought to my notice that

*Jour. d. Bot. 12: 230. *5 f.* 12: 380. 1898. Bot. Gazette 28: 136. 1899.
†Ber. d. Deutsch. Bot. Gesell. 16: 203-207. 1898.
‡Ber. d. Deutsch. Bot. Gesell. 16: 207-214. *pl. 13.* 1898.
§The sleepy grass. Garden and Forest. 4: 111.

cattle are affected in a similar way to horses, and that the curious properties which so effect animals are contained in the blades. Quite a number of our horses have been ill this spring after having eaten it. It usually takes them about a week to recover, during which time they are unfit for work, and especially so during the first three days.'

Fig. 74 A. One of the grasses referred to as sleepy grass *Stipa viridula.* (After F. Lamson-Scribner Div. of Agrost. U. S. Dept. of Agri.)

"Captain Kingsbury, of the Sixth United States cavalry, under date of March, 1890, wrote me from Fort Stanton that the sleepy grass affected nearly all his horses at two camping places. It was hard work to make them walk.

"The similarity of symptoms, whether observed in Coahuila or in New Mexico, is certainly remarkable, and furnishes strong evidence of the substantial accuracy of the observations as

reported. It would seem, then, reasonably established that this plant possesses narcotic or sedative properties, affecting principally horses, but also cattle and probably other animals; that animals are not fond of it, but eat of it inadvertently or when under stress of hunger; that cases of poisoning occur especially in the spring, when the radicle and lower blades first come up, and that the active principle resides in these blades, and perhaps only during that season."

The old world species *Stipa inebrians* is said to affect animals like *S. robusta* referred to by Dr. Havard.

Millets.—Several millets, and especially Koda millet (*Paspalum scrobiculatum*), are known to be poisonous and injurious. According to Grant, several well-known cases of poisoning resulted from the consumption of this grass largely used because of the scarcity of food grains. He suggests that it is due to a poisonous volatile alkaloid. There have been numerous complaints, from time to time, from the injurious effects of millet *Setaria italica* when fed to horses and cattle.

Dr. Hinebauch* states in regard to this trouble that in the winter of 1891 and 1892 a disease commonly called millet disease was prevalent to a considerable extent in North Dakota. That this disease was attended by a death rate of 7 to 10 per cent. It received the name of millet disease from the fact that from 95 to 98 per cent of the animals that were affected had been fed on millet. He says: "When millet is fed in considerable quantities it stimulates the kidneys to increased action. The urine is light colored and the bladder evacuated every two or three hours, large quantities of water being passed at each time. At the time the first symptoms of lameness were noticed, the kidneys had almost ceased to act." And then he goes on to say: "When the cause was kept up a sufficient length of time for the reaction to set in, the material which would under normal conditions be secreted by the kidneys is allowed to remain in the system and produce deleterious effects." Apparently the condition of the millet had little to do with this action. In a later bulletin† on the same subject Dr. Hinebauch reports a more extended investigation, giving considerable experimental data as well as urinary analyses. The post mortem examinations revealed some interesting facts. The cartilages on the ends of the long bones show deep furrows run-

*Rheumatism in horses. Bull. Gov. Agrl. Exp. Sta.. N. Dak. 7: 1892.

†Feeding of millet to horses. Bull. Gov. Agrl. Exp. Sta. N. Dakota. 26: 1896.

Fig. 74 AA. Shama millet (*Panicum colonum*), *a*, *b*, *c*, *d*, different views of the spikelet and glumes; *e*, *f*, two views of the "seed" (Div. of Agrostology U. S. Dept. of Agri.)

ning in a direction parallel with the motion during flexion and extension.

"Both grooves of the astragalus were partially denuded of cartilage, so that the corresponding elevations of the tibia which articulate in the grooves did not have cartilage interposed between them. The whole general appearance, instead of being of a white, glistening color, was of a dark, dull color bordering on brown. The fluid which escaped from the joint when opened, instead of being a yellow, amber color, was brown and contained red blood corpuscles, indicating that inflammation was present. The joint fluid was brownish black in color and contained red blood corpuscles.

"In conclusion we would say that our experiments here have thoroughly demonstrated that millet, when used entirely as a coarse food, is injurious to horses. First. In producing an increased action of the kidneys. Second. In causing lameness and swelling of the joints. Third. In producing infusion of the blood into the joints. Fourth. In destroying the texture of the bone, rendering it softer and less tenacious, so that traction causes the ligaments and muscles to be torn loose. The experience of many farmers with whom I have talked confirms the above conclusion, and we could multiply case after case showing that the above conditions are the results of feeding millet."

Very recently the North Dakota Station has published the results of further experiments on the subject of feeding millet. Two tests were made. In the first trial two geldings in good health were fed hay and grain for about two weeks. Millet was then substituted for hay for about ten days.

Recently Ladd* has isolated a glucoside from the aqueous extract of millet hay, which, when fed in small quantities, gave the characteristic symptoms.

From the experiments made by Dr. Hinebauch and others, it would appear that feeding millets alone as coarse fodder is injurious to horses. It produces an increased action of the kidneys, and causes lameness and swelling of the joints. It causes an infusion of blood into the joints, and destroys the texture of the bone, rendering it soft and less tenacious, so that the ligaments and muscles are easily torn loose.

In a paper on millet by A. A. Crozier,† the experience of several farmers is given as to whether millet is injurious or not. The testimony given differs greatly. Some claim it is injurious while others claim it is not. The condition of maturity seems to make a difference as to its injurious qualities.

Mechanical Injuries and Obstructions.

Awned grasses.—Under the subject of dissemination, reference was made to the subject of the fruits of stipa burying themselves in the flesh of sheep and other animals. It has long been known that the *Stipa capillata, L.*, indigenous to Russia, and the *Stipa spartea*, native to North America, as well as *Aristida hygrometrica Br.*, native of Queensland, and *Heteropogon contortus*, native of New

*Am. Chem. Jour. 20: 862.

†Millet, Bull. Mich. Agrl. Coll Exp. Sta. 117: 14. 1894.

Caledonia frequently bore in to the skin and intestines where they cause fatal inflammation. The following very full account is from Dr. M. Stalker:* "You ask whether the fruits of the porcupine grass (*Stipa spartea*) are ever a source of inconvenience or injury to living animals? This may be very emphatically answered in the affirmative. In many of the northwestern

Fig. 74 B. Needle grass (*Stipa comata*) *a*, spikelet showing awned fruit; *b*, lower glumes removed. (After Lamson-Scribner, Div. of Agrost. U. S. Dept. of Agrl.)

counties of Iowa this grass grows in the greatest profusion, and during the latter part of June, the season for maturing and consequent falling of these spines, they are the occasion of much annoyance and in some instances the death of domestic animals. Only such animals as are covered with wool or a thick growth of long hair are seriously inconvenienced. Sheep suffer most. The spines readily find a lodgment in the wool,

*Bessey. Injuriousness of Porcupine grass. Am. Nat. 18: 939. 1884.

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and after burrowing through it frequently penetrate the skin and bury themselves in the flesh. A large number of these barbs thus entering the tissues of the body produce an amount of irritation that is sometimes followed by death. I have seen large numbers of these imbedded in the skin and muscular tissues of shepherd dogs that were covered with a thick growth of soft hair. These sagacious animals frequently exihit the greatest dread at being sent into the grass during the season of danger."

Professor Bessey in his account of the structure of this plant received several responses, and one of these was from Professor King, now of the University of Wisconsin. "In connection with the two notes relating to the fruit of the porcupine grass, it may not be without interest to say that while engaged in geological work in Dakota, north of the Northern Pacific railroad, we were much annoyed by the fruit of this grass. Indeed, I found the only way to walk with comfort through this grass was to roll my pants above my knees and my socks down over my shoes. I also observed, on several occasions, these seeds planted two inches deep in the soil with the awns protruding from the ground. It is plain that with the point of one of these fruits once entered below the soil, the swelling and shrinking, due to varying amounts of moisture, would work the seeds directly into the ground."

The *Stipa comata*, or needle grass of the west, which is common throughout the Dakotas, and throughout west Dakota, Nebraska, Wyoming and Colorado, is common in prairie hay, and Prof. Thomas A. Williams* mentions that, though a forage plant, and not cut until the needles have fallen so that the stock may not be injured, the fruit of this plant often injures stock to a considerable extent.

Corn stalks.—For a long time farmers in the west and other parts of the United States have been troubled with the so-called corn stalk disease. This has been attributed to various causes, as impaction of the stomach and a bacterial disease. Dr. Mayo, of the Kansas Agricultural Experiment Station, attributed it to an excess of potassium nitrate in the stalks.

Injuries from barley.—It has long been known that the barbed awns of barley, wild barley and other plants act injuriously in a mechanical way. In the west this is especially true of wild

*Grasses and forage plants of the Dakotas. Bull. U. S. Dept. Agrl. Div. Agrostology. 6: 20.

Fig. 75 A. Squirrel-tail or wild barley; *b*, spikelets; *c*, *d*, flower. (King.)

barley, *Hordeum jubatum*. Dr. S. H. Johnson,* of Carroll, states in the Carroll Herald, that this grass, when found in hay and allowed to ripen, if in any quantity, is very injurious to horses' mouths. He says: "The small awns seem to work in and cause deep ulcerating sores, which form under the tongue and lips. The writer has seen a large number affected and made a careful examination, and found them deep in the flesh, where they had remained for three months or more. I have seen lips eaten completely through and tongues eaten almost off by the grass. As to cattle, I have seen some affected, but not to any extent, because the mucous membranes are much thicker. The sooner the grass is eradicated the better."

Professor Nelson,† who has carefully studied this question, says on the injury to stock: "The awned heads, when taken into the mouth, break up into numerous sections, scatter about within the mouth and everywhere adhere to the mucus membrane, which soon becomes pierced with the long, stiff awns. As the animal continues to feed more awns are added, and those already present are pushed deeper into the flesh. Inflammation soon results and leaves the gums of the animal in a condition to be more easily penetrated. The awns are particularly liable to be pushed down and alongside and between the teeth. As the swelling and festering progresses the awns are packed in tighter and pushed deeper and cause suppuration of the gums as well as ulceration of the jaw bones and the teeth. Through the absorption of the ulcerated sockets and roots the teeth

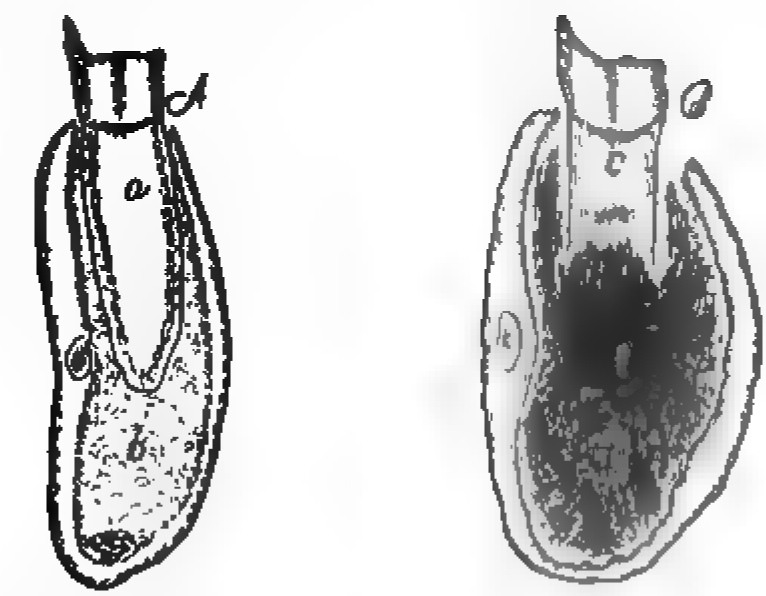


Fig. 76 B. Cross-section of normal jawbone; *a*, fang of tooth; *b*, marrow. B—Cross-section ulcerated and enlarged jawbone; *c*, decayed fang of loosened tooth; *d*, cavity in enlarged jaw, the embedded awns removed.

*Carroll Herald. 1896: 28 j.
†Squirrel-tail Grass. Bull. Wyoming Agrl. Exp. Sta. 19.

become loosened and even drop out, but the animal, impelled by hunger, still endeavors to eat such hay as may be offered."

There are also cases on record where these awns produce hair balls. An interesting account of hair-balls may be found in a paper by Dr. Trelease.* "Barbed trichomes and barbed

Fig. 75 O. Little barley (*Hordeum pusillum*) probably also causes mechanical injuries. (F. Lamson-Scribner Div. of Agrost. U. S. Dept. of Agri.)

stiff bristles have been known to cause serious injury to stock Professor Coville has recently called attention to some of these coming from a plant that has had considerable advertising as a forage plant, Crimson Clover (*Trifolium incarnatum*). Professor Coville† says: "The crimson clover hair-balls, measur-

*An unusual Phyto-Bezoar. Trans. Acad. Sci. St. Louis. 7; 493. pl. 40.
†Bot. Gazette. 20: 414.

ing two or three inches in diameter, were taken from the stomach of horses, whose death they had caused. They were compact and much resembled the hair-balls often found in the stomachs of ruminants, but were entirely composed of the small barbed trichomes from the mature calyx of crimson clover." Millets are said also to produce "masses" probably hair-balls according to a writer* in the American Agriculturist.

Harz† has given an account of the injurious effects of oats bran. This feed favors the development of large bezoars. In the paper cited he has extensively discussed this question as well as giving references to literature.

Corn Moulds and Disease.

It is not uncommon some years to find that many ears of corn are affected with various moulds. These moulds frequently appear as the results of the attack of *Heliothis armigera*; however, this is not always the case. Sometimes only the top is affected, or only a part of the ear both at lower and upper end, or several rows may be attacked. These moulds are mostly saprophytes, and so far as known do not attack living tissues. One of the most frequent of the moulds is the green mould *Eurotium* (*Aspergillus*) *glaucus* which is described elsewhere in this paper.

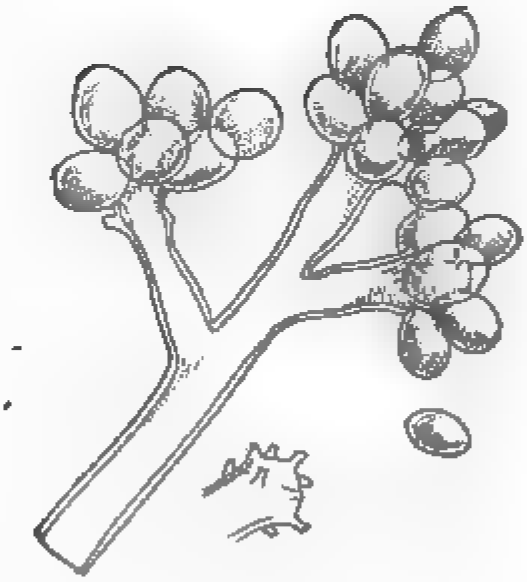


Fig. 78. Mould from mouldy corn (*Botrytis vulgaris*), showing conidiophore and spores. (Pammel and King.)

N. S. Mayo,‡ as the result of some work done in Kansas, concludes that a disease known as "staggers," "mad staggers," or as he has termed it *enzootic cerebritis* is caused by feeding corn which is attacked by *Aspergillus glaucus*. Mayo states that the spores of the fungus gain entrance to the circulation, and find lodgment in the kidneys and liver. He supports his conclusions by experiments made by him on a guinea pig and a young colt. He also quotes Kaufmann, who was successful in producing a disease with *Penicillum glaucum* and *Aspergillus glaucus*.

*1882: 127.
†Harz. Land. Samenk. 2: 1215.
‡Bull. Kansas Agrl. Exp. Station 24: 1891.

There is considerable loss in many states from cerebro-spinal meningitis. In many parts of the country this is attributed, as I have said before, to mouldy corn. Dr. Bitting,* of the Indiana Agricultural Experiment Station, made an investigation of this question and concludes that mouldy corn is not responsible for this disease. Upon an examination of mouldy corn he found several moulds and a bacterium. To test the poisonous properties, two horses were injected under the skin with five cubic centimeters of the active growth in boullion of the bacterium found in mouldy corn, and later followed by an injection of ten centimeters. Later larger amounts were given, and each animal was induced to eat as much as five pounds of the infected meal per day. One of the moulds as well as the bacterium gave negative results; the Fusarium produced a redness of the gums and some salivation. In no case did cerebro-spinal meningitis result.

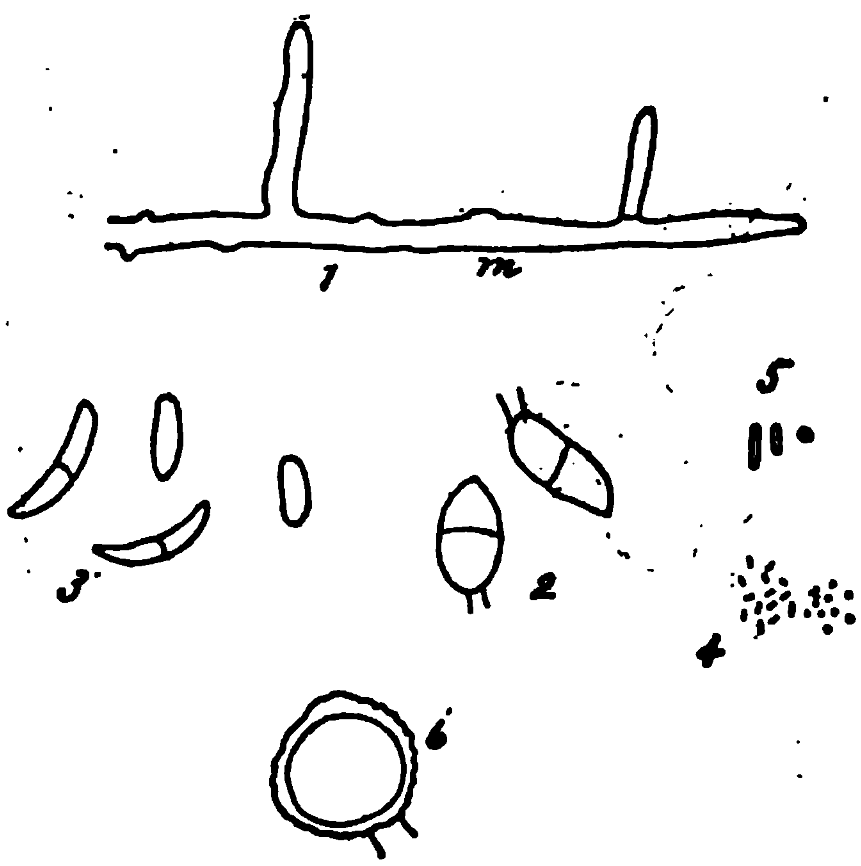


Fig. 77. Moulds and bacteria from mouldy corn. 1 and 3, Fusarium; 1, mycelium; 2 and 6, other moulds; 4 and 5, bacteria. (Pammel and King.)

The results of the experiment show that inoculations with culture of the bacteria and moulds were ineffective. Eating of the mushes containing pure culture showed that only in the case of a growth of a species of Fusarium did any intestinal disturbance follow, and that in one case the feeding of the rotted grain produced considerable intestinal disturbance and some nervous symptoms, but that the disturbance was light in the other.

Grawitz succeeded in producing infection by adapting the digestive tract of the animals to an alkaline medium. It is a

*Farmers' Bulletin U. S. Dept. Agrl. Exp. Sta. Work. XVI. 123: 26.

well-known fact that several of the moulds related to Asperillus are the cause of what is called mycosis in many of the lower animals. *Aspergillus glaucus* or, more properly speaking, the *Eurotium* (*Aspergillus*) *glaucus* is extremely common not only in hay but in many other objects, and yet this disease is very rare. This question should be further investigated.

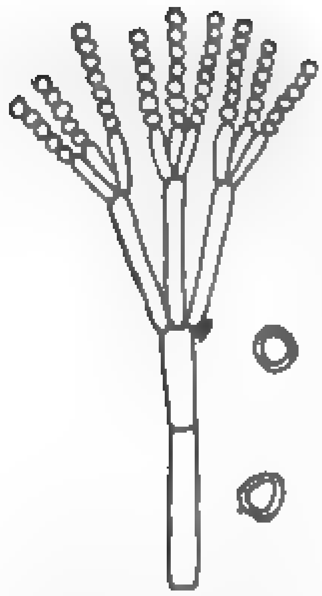


Fig. 78. Common blue mould (*Penicillium glaucum*). Spores at end of branches; spores borne in chains. (Pammel and King.)

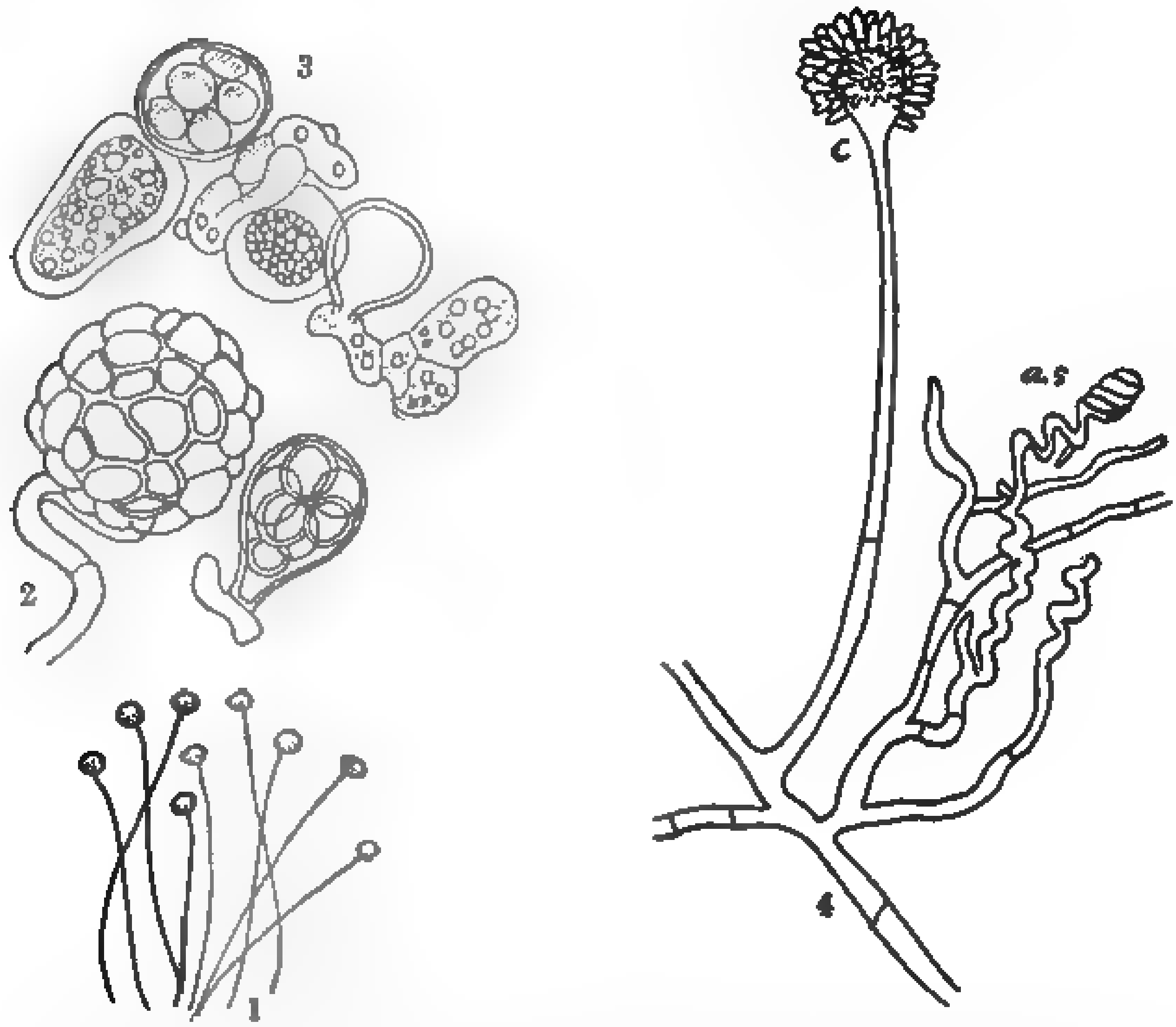


Fig. 79. Common Herbarium mould. (1) general appearance, showing long conidiophore and sterigmata on end; (2) perithecium with one of its asci and ascospores; (3) contents from an unripe perithecium; (4) a small part of a mycelium with conidiophore *c*, and spore bearing sterigmata, young ascogonium *a. s.* (DeBary except 1.)

Fungus Diseases of Grasses.

A large number of our forage plants are subject to serious fungus diseases, which materially lessen the crop. While these diseases are most severe to the cereals, where they annually entail a loss of millions of dollars, many of our best forage grasses are subject to most destructive rusts and smuts. One way to overcome these dangerous pests is in a study of their life history to see if methods of culture cannot improve the

Fig. 80. Downy mildew of millet (*Sclerospora graminicola.*) The leaves partially disintegrated; a, leaf magnified; b, conidia; c, conidiophore bearing conidia (spores) (Pammel and King.)

Fig. 81. *Sclerospora graminicola.* Leaves torn up into shreds, filled with oospores. (King.)

quality of the product or render the plant less susceptible to the disease. Much in the following pages has been gleaned from various sources, as well as work of our own based on experiments extending over a period of years.

DOWNY MILDEW.

This disease is caused by *Sclerospora graminicola (Sacc.) Schroet.* Though a large number of plants belonging to many different

Fig. [illegible]. To the left leaf of *Setaria viridis* containing the oospores of *Sclerospora graminicola*, a single spore at (*a*). (After Trelease.) To the right spike affected by the same fungus; (*b*) single spikelet enlarged. (After Halsted.)

orders of flowering plants are affected by downy mildews, few of these pests are found on grasses. This fungus, though well-known for some years in Germany and Italy, has not been long known in this country. It was first reported in Wisconsin, as occurring on Hungarian grass (*Setaria italica*) and foxtail and pigeon grass (*Setaria viridis*). Dr. Halsted* reported it from Iowa on the last named host in 1886, and the next year on Hungarian grass.

It is now common throughout the state of Iowa. The fungus has been found by the writer quite as common in Nebraska as in Iowa. Webber† gives its distribution in that state; Ashland, Weeping Water (Williams), Lincoln (Bessey), where he found it on green and yellow foxtail (*Setaria viridis*, *S. glauca*). have also received it from North Dakota, where it was collected by Prof. Bolley. Like many other pests, it comes from Europe, and in all probability was brought to this country with the seed of either Hungarian or foxtail, as both grasses are native to that continent.

Little mention is made of this fungus by Tubeuf,‡ and it is not mentioned by Loverdo.§ The account by Sorauer is short. A good account was given by Trelease;‖ it was also described by Farlow.¶

Halsted,** who found it common here at Ames, reported on it in several publications.

The fungus produces a mycelium in the interior of the leaves and soon sends short branches conidiophores through the stomata. These bear the conidia, the summer reproductive bodies. Last spring I had an opportunity of observing an unusually large number of young diseased plants. A white frosty-like substance (the conidia and conidiophores) appeared on the leaf in patches extending along the veins. The opposite side of the leaf was invariably of a yellowish color. In July and August the summer spores are not so commonly seen, especially in the older leaves. Last spring the weather was quite favorable for the development of this fungus. Young plants affected soon

*Trelease. Parasitic fungi of Wis. 7.

*Bot. Gaz. 11: 273.

†App. to Cat. Fl. Nebr. Contr. Shaw School Bot. 9: 11. Trans. Acad. Sci. St. Louis. 6.

‡Pflanzenkrankheiten. 153.

§Les maladies des cereales.

‖In Beal. Grasses of No. Am. 1: 429.

¶Bot. Gaz. 9: 39.

**Bot. Gaz. 11: 273. 13: 56. Bull. Iowa Agrl. Coll. Dept. Bot. 1886: 53. Bull. Dept. Bot. Iowa Agrl. Coll. 1888: 99.

succumbed to the disease, the leaves wilted and soon rotted. Later in the season the leaves of older plants being more rigid, did not show this rotting, but many of the leaves of the affected plants are brown and torn up into fine shreds. A little shaking will bring out a large number of small round bodies, the oospores; these are enclosed in a thick cell-wall. The spikes are also frequently attacked, producing large distortions. The pistil and stamens do not develop, while the bracts surrounding the essential organs are greatly lengthened. Thus in some affected spikes of Golden Wonder millet and Hungarian grass the distortions were so large that they were not recognizable. The oospores are so numerous as to fill up the tissue between the epidermal cells. The oospores serve to carry the fungus over winter. It is not a difficult matter, if the seed is purchased from an infected district, to carry the disease to remote distances, as it is a comparatively easy matter for some of the bracts containing spores to get in with the seed, or for some of the spores to become attached to the seeds.

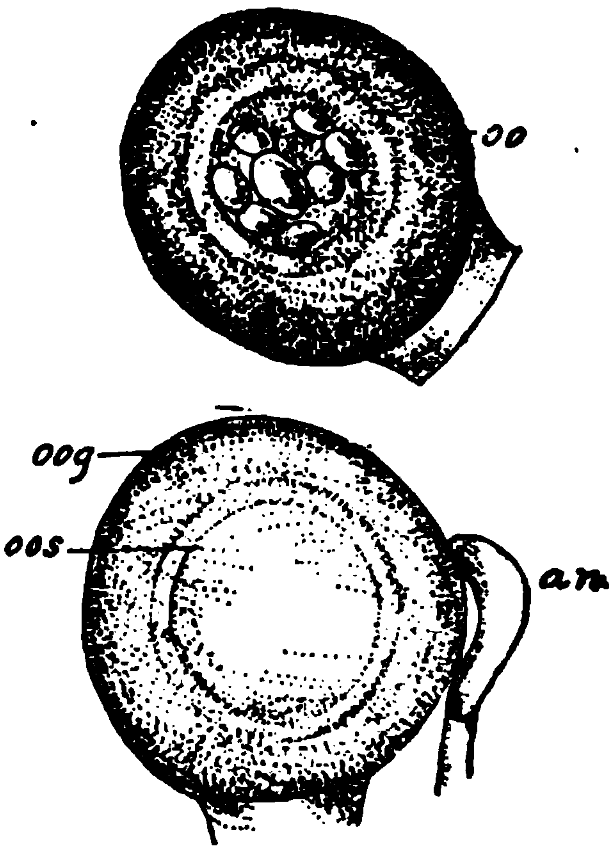


Fig. 83. Downy mildew of Hungarian grass *Sclerospora graminicola*; *oog*, oogonium; *oos*, oosphere; *an*, antheridium; *oo*, oospore. (Pammel and King.)

Mildew of Indian corn.—In a recent German scientific periodical, M. Raciborski describes a very destructive downy mildew of corn which he has named *Peronospora maydis*. Many of the fungi of this group cause great loss, as for example the potato rot fungus, downy mildew of the grape, and others which might be mentioned. This fungus of the corn is no exception to the rule. It has been found but in one place in Java. No doubt, however, it will spread and may yet become a source of danger to us. The fact of its occurrence in Java is of interest, because corn is not native there. The author looked for it on native grasses, but failed to find any indications of its occurrence.

Where did the fungus originate? Most probably on some other grass and from that spread to the corn. The descriptions and figures suggest the similar European fungus on millet, *Sclerospora graminicola* described above. In Java the fungus is

known as "lijer" which means sleepy or tired. It makes its appearance on young plants. The second and third leaves are usually green. On the fourth and subsequent leaves the disease is easily recognized from a distance, as the plants are white or yellowish white. Either the entire leaves are affected or it forms bands. The young plants fall over. In the tissues of such plants an abundance of an undivided mycelium occurs It has numerous haustoria or suckers which enable the mycelium to take up its nourishment. On the surface of the leaf may be seen a thick white mold, the fruiting threads of the fungus. These make their way through the stomata and bear summer reproductive bodies which germinate in a few hours. Young infected plants show these fruiting bodies in eight to twelve days.

In addition to these reproductive bodies resting spores known as oospores also occur abundantly, especially in the stems and leaf sheaths. Natural infection results by the wind which carries the spores, also from the oospores which may retain their vitality for some time. The writer suggests that the young diseased plants be pulled up with the root and burned. It is not likely that this fungus has been found on corn in this country. It may be expected, however, somewhere on this side of the Atlantic and may prove injurious.*

ERGOT (CLAVICEPS PURPUREA (FR.) TUL).

The subject of ergot is one of considerable importance to the Iowa stockman. Scarcely a year passes but complaints are received about the injurious effects to cattle from the use of fodder that contains ergot.

History.—It may not be out of place to briefly refer to the history of ergotism. Epidemics of ergotism have, without doubt, been correctly referred, even before the tenth century. Wood states that epidemics of ergotism or chronic ergotic poisoning have been recorded from time to time since the days of Galen (130–200 A. D.) and of Caesar (B. C. 190–44). From the ninth to the thirteenth century epidemics were frequent in France, and in the twelfth in Spain. They were first called plagues but later received special names. In 1596 Hesse and adjoining provinces were visited by this plague which was attributed to the presence of ergot in grain. In the epidemic in Silesia in 1722, the king of Prussia ordered an exchange of

*L. H. Pammel. Mildew of Indian Corn. American Agriculturist 61: 708.

*Raciborski Lijer, eine gefahrliche Maiskrankheit. Ber. der Deutsh. Bot. Gesell. 15: 475–478. 1897.

Fig. 84 Ergot on blue grass; to the right leaf of blue grass with uredo pustules of *Puccinia poarum*.

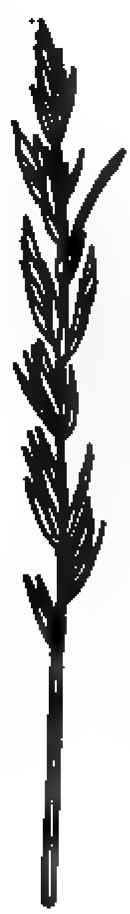


Fig. 85. Ergot (*Claviceps purpurea*) on Agropyron. (King.)
Fig. 86. Ergot on blue grass 1. Ergot on wild rye 2. (After Salmon.)

sound rye for the affected grain. Freiburg was visited in 1702, Switzerland in 1715–16, Saxony in 1716, and other districts of Germany in 1717, 1736, 1741–42. France was visited in 1650, 1670 and 1674. From 1765 to 1769 it was abundant in Sweden in rye and barley. Linnaeus attributed it to the grain of *Raphanus raphanistrum*, which was incorrect. The last great epidemic in Europe occurred in France in 1816, in Lorraine and Burgundy; it was especially fatal to the poorer inhabitants.

It has been observed that these epidemics follow a rainy season. Fleming states that in 1041, when the weather was so unpropitious, tempests, rains, and inundations occurring, many cattle perished from the disease. "In 1098, after inundations and heavy fogs, there was a general epizooty among cattle in Germany. In the same year ergotism appeared in the human species."

History in America.—Dr. Randall, in 1849, called attention to a disease in New York, in which the involved parts were finally invariably affected with dry gangrene. He states that in the severe climate of New York farmers allow their cattle to winter in the fields on blue grass (*Poa pratensis*) which is rich in ergot. A disease known as "hoof-ail" was correctly ascribed to ergot by James Mease, of Philadelphia, prior to 1838. The disease was quite severe in Orange county, New York, in 1820. It was minutely described by Arnell. In 1857 the disease was quite severe in Portage county, Ohio. A committee appointed by the Farmers' Association of Edinburg reported that the disease was due to ergot in hay. In recent years* epizootics of ergotism have been reported by Law in New York, Stalker in Iowa, and Faville in Colorado. The most serious outbreak in recent years occurred in Kansas in 1884. This caused considerable excitement since at first it was diagnosed as "foot-and-mouth disease." Salmon, who examined some of the hay from several localities in Kansas, found a large proportion of wild rye (*Elymus virginicus*, var. *submuticus*) to contain a large quantity of ergot. In one case 12 per cent, and in another 10 per cent was found. From this he estimated that from 5 to 6 per cent of the entire weight of the plant must have been ergot and that a twenty-pound ration of hay would contain four ounces of ergot.

*See Salmon on Contagious Diseases of Domestic Animals. 1883-1884: Where an extended history is given, and Fleming Animal Plagues, their history, nature and prevention. 1: 1871. 2: 1882.

Nature of ergot.—Ergot is a stage of a minute parasitic fungus. Although its true nature was not known by early writers, it is mentioned by many of the earlier botanical writers. Lonicer*, about the middle of the sixteenth century, mentions

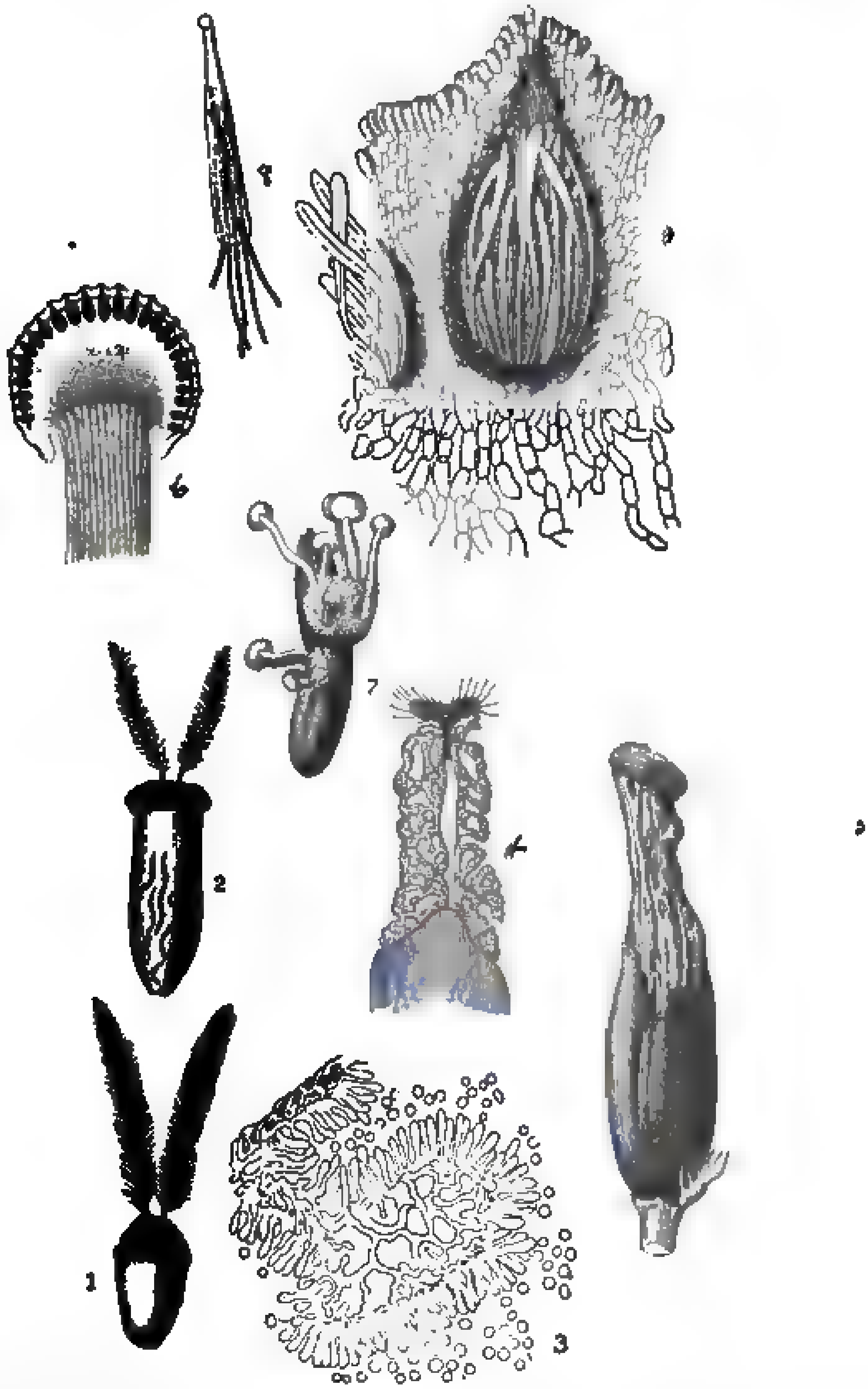


Fig 87. Ergot (*Claviceps purpurea*). *1*, normal ovary of rye; 2, young ovary of rye infested with ergot; *3*, cross section of ovary showing mycelium and spores on surface, the sphacelial stage; 4 upper part of ergotized grain with spongy sphacelial mass; to the right of 4 mature ergot; 7, ergot germinating; *6*, section through club-shaped mass and flask-shaped perithecia; *9*, perithecia enlarged with asci; *8*, ascus with ascospores. (After Tulasne from Salmon.)

*Kreuterbuch. 285. 1582.

its specific use. Thalius* (1588) applied the name of "ad sistendum sanguineum."

Bauhin† used the name of *Secale luxurians*. De Candolle‡ applied to it the name of *Sclerotium clavus*. Although other names have been applied to it, the credit of working out the life history belongs to Tulasne, one of the most eminent of French mycologists.

Characters of the fungus and development.—There are still many persons who believe that ergot is a degenerate kernel of rye or wheat, but the researches of Tulasne and other mycologists have laid at rest many of the vague theories concerning it. The black, purple, or dark gray spurs found in the flowers of rye, wheat, and other grasses are simply one stage of a parasitic fungus, known as *Claviceps purpurea*, Tul. These spurs consist of a compact mass of threads known as the sclerotium stage; it was formerly called *Sclerotium clavus*.

No changes occur in ergot while it remains in the head, but the following spring, when laid on damp earth, it produces at different points small, roundish patches which are somewhat elevated. Soon a small white head appears which elongates, becoming stalked, and bearing a globular head at the tip. These heads change from a grayish yellow to a pinkish color. A cross section shows that the central portion is made up of closely woven hyphae or fungus threads, while the edge contains a number of flask-shaped bodies, the perithecia, in which are found elongated bodies known as asci; each ascus contains eight filiform spores, the ascospores. The ascospores germinate and when coming in contact with a very young ovary the mycelium penetrates the delicate walls of the ovary and gradually displaces it. It is quite easy to trace out its life history by placing the ergot in damp sand and allowing it to remain over winter.

The first indication of ergot in the summer is the formation of the so-called honey-dew, a sweetish and rather disagreeable fluid, which is eagerly sought by flies and other insects which feed upon it. This fluid contains a large number of small spores, so that insects can readily carry the fungus from a diseased ovary to one not diseased. These spores germinate immediately. This stage is called the sphacelia, and formerly was held to be

*Silva Hercynia. 1588. 47. Francfourt.
†Pinax. Theatri Botanica. 23. 1623.
‡Mem. du Mus. 2: 401. *pl.* 14. *f.* 8.

a distinct fungus. In this stage the mass which has replaced the ovary is soft, but as it becomes older it hardens; ultimately a hard and compact mass, the ergot, is formed.

Chemical composition of ergot.—The grain contains about 30 per cent of a yellowish oil, consisting of fats, principally olein and palmitin. It contains, according to Wenzell, two alkaloids, ecboline and ergotine, which are said to be the active principles of the drug. Another alkaloid, ergotinine, has also been isolated, but according to Kobert,* ergot contains three poisonous substances. These are cornutin, an alkaloid having a specific action on the uterus, causing it to contract; sphacelic acid, a non-crystalizable and non-nitrogenous substance which causes the poisoning and gangrene; ergotinic acid, a nitrogenous glucoside without action on the uterus and narcotic in its effect. Besides these substances it contains others, prominent among them being a sugar called mycose, which is also present in other fungi.

Medical use.—Ergot has long been used in medicine on account of its specific action on the uterus. Its effects are (1) gastroenteritic, causing salivation, inflammation and diarrhoea; (2) a dry gangrene of the extremities, hoofs, ears, tail, etc.; (3) contraction of the uterus and, as a consequence, abortion; (4) want of feeling, lameness.

Cereals affected.—Rye is more subject to it than any of the other cultivated cereals. The largest specimens are usually produced on isolated specimens of rye coming up in fields. It seldom happens that all of the ovaries are affected. Wheat, especially winter wheat, is subject to the disease. The officinal ergot is usually obtained from rye.

Wild grasses.—Of our native grasses, wild ryes (*Elymus robustus*, *E. virginicus*, *E. striatus*, *E. canadensis*, *Asprella hystrix*) are most subject to the disease. Most cases of ergotism in this state undoubtedly result from the ergot of *Elymus robustus*, which is a common everywhere. *Agropryon spicatum*, a grass not uncommon in northwestern Iowa, and Quack grass (*Agropyron repens*), are also much subject to its attacks. Scarcely a head of the two species cultivated on the college farm could be found which did not have some ergot. This may be for the same reason that it occurs most abundantly on rye, namely, that the grasses occurred in isolated places. In some pastures, timothy (*Phleum pratense*), is much subject to the attack of *Claviceps*

*Froehner: Lehrb. d. Toxologie f. Thierarzte, 1890.

purpurea. Thus in Wisconsin I observed a large percentage of timothy in an old pasture which contained many heads which were ergotized. Blue grass (*Poa pratensis*), *Poa annua*, *Calamagrostis canadensis*, *Agrostis vulgaris*, *Glyceria fluitans*, and many others, in some seasons and localities, are diseased.

Other forms of ergot.—It may be possible that some of the forms of ergot on grass may be referred to other species. Halsted states, however, that the ergot on *Elymus robustus* is *Claviceps purpurea*. The *Hordeum jubatum* contained apparently the same species, with some minor differences but these are due to the nature of the host.* The *Claviceps microcephala* (Wallr) Tul. occurs on *Phragmites*, *C. setulosa* (Quel) Sacc with a yellow stroma on Poa, and *C. pusilla Ces* on *Andropogon Ischaemum*.

Preventative measures.—With modern methods of cleaning cereals there need be little fear of the presence of ergot in flour but it still continues to be a decided menace to cattle, especially where it develops in our grasses, as timothy, blue grass, red top, and wild rye. It is imperative to cut all of these grasses before the ergot is mature. The presence of ergot in these wild grasses no doubt causes its spread to wheat and rye fields. Von Thumen thinks that the *Lolium perenne*, so commonly cultivated in Europe, is largely responsible for its abundance in Austria.† He emphasizes the importance of cutting the grass in waste places several times during the year to prevent the formation of ergot.

CAT-TAIL FUNGUS.

Cat-tail fungus, *Epichloe typhina* (Pers.) Tul. This fungus was described by Persoon‡ as *Sphaeria typhina* in 1801 and by him recognized as parasitic. Tulasne§ transferred it from the genus Sphaeria to that of Epichloe. It has been described from an economic standpoint by several mycologists—Sorauer‖, De Bary¶, Trelease**, Frank†† and Tubeuf‡‡.

This fungus is occasionally very abundant and destructive to timothy, and occurs occasionally on other grasses, notably

*Bull. Dept. of Bot. Iowa Agrl. Col. Ames. 1886: 19.
*Bull. Dept. of Bot. Iowa Agrl. Col. Ames. 1888: 8.
†Die Bekampfung der Pilzkrankheiten unserer Culturgewaechse. 36.
‡Syn. method. fungorum. 29.
§Selecta fungorum. 3: 24.
‖Pflanzenkrankheiten. 410.
¶Flora. 1863: 401 Bot. Zeit. 1865: 100. (According to Sorauer, 411).
**In Beal. Grasses of No. Am. 1: 423 (Ed. 1.)
††Krankheiten d. Pflanzen 458. *f. 81* (Ed. 2.)
‡‡Pflanzenkrankheiten. 207.

Fig. 87A. Oat-tail fungus (*Epichloe typhina*) on timothy. (King.)

Poa, Elymus and Dactylis. The fungus produces a whitish stroma, which surrounds the grass culm near the upper leaf sheaths. This velvety ring consists of a loosely arranged mycelium which takes the nourishment from the grass plant, causing the parts above the ring to die, since it prevents the conductingof food to the leaves above. This stroma produces small, one-celled conidia borne on conidiophores. As the stroma becomes yellow, deep-seated perithecia occur. These contain the asci in which eight hyaline ascospores are found. The fungus spreads from a center of infection to neighboring stalks, especially by means of the conidia. To prevent the fungus from spreading it is advisable to cut the grass at the time the fungus appears on the young plants.

HYPOCRELLA (HYPOXYLON (PK. SACC.)

This fungus is closely related to the preceding. It produces a thin grayish stroma which usually becomes black and extends along the upper surface of the leaf or surrounds the culm. The perithecia are small and crowded; the asci narrow and linear; the ascospores linear, colorless, with numerous nuclei.*

The fungus attacks living grass, stems and leaves.

POWDERY MILDEW OF GRASSES.

The powdery mildew (*Erysiphe graminis* D. C.) is a serious fungus disease at times. It was described by DeCandolle† and has been noted by several writers.‡

Every one who has had occasion to walk through a blue grass meadow after a rain, especially in damp and shaded places close to the ground, must have noticed a white mealy covering on the blades of many of the leaves. The Germans have called this mehlthau (literally translated meal dew) which

*Saccardo Syll. Fung. 2: 581.
Ellis and Everhart. N. Am. Pyrenenycetes. 91.
Peck. Rep. Mus. State Nat. Hist. 27: 108.

†Fl. Franc. 6: 106. For synonymy see Loverdo Les Maladies Crypt. 212.

‡Sorauer. Pflanzenkrankheiten. 231.
Frank. Krankheiten d. Pflanzen. 554. (Ed. 1.) 264. *f.* 51. (Ed. 2.)
Tubeuf. Pflanzenkrankheiten. 194.
Trelease in. Beal. Grasses of N. Am. 1: 423.
Pammel. Fungus diseases of Iowa Forage Plants. 14-15.

is certainly very expressive of its appearance. An examination with a microscope will show that this white substance is composed of spores and a mycelium. The mycelium is cobwebby and spreads over the surface, but does not penetrate the leaf. In numerous places erect branches are produced, these bear numerous spores. This stage was formerly called *Oidium monilioides*. Called Oidium because the spores resemble an egg. In all cases of Oidium this is not true; the species was called monilioides because necklace like, referring to the manner in which the spores are borne. Worthington G. Smith states the spores are so numerous that it would take about a million spores to cover a square inch.

These conidia or summer spores germinate, under favorable conditions, in from ten to sixteen hours. The temperature most favorable for germination is from 17–26 C. In a powdery mildew occurring on the squirrel-tail grass, and supposed to be the same fungus, these spores are also capable of immediate germination. On blue grass the fungus frequently does not produce perithecia but ends its existence with the formation of conidia.

Under favorable conditions, especially moisture and damp weather, the fungus spreads rapidly. The leaf of grass affected by this fungus soon dries up. When the leaves have become dry and the affected plants are disturbed a little, clouds of dust arise, especially in shady places. The perfect stage of the fungus is not of common occurrence, though if careful search is made in the fall, small black specks may be seen; these are the perithecia and contain the asci and ascospores. It is the resting stage or winter condition of the fungus. The writer found the perfect fungus abundant on *Poa wolfii* in Colorado, and Carver found it abundant on blue grass near Ames one season. The Oidium stage does not retain its power of germination very long, but the ascospores contained in the perithecium germinate the following spring, and when the tube comes in contact with the proper host the mycelium spreads over the surface of the leaf and causes the mealy appearance.

Plants affected.—It affects especially blue grass with us and is much worse some seasons than others. English investigators report that this fungus is most abundant when slight frosts occur, also with heavy rains and wet soils. Texas blue grass (*Poa arachnifera*), fowl meadow grass (*Poa serotina*), *Eatonia obtusata*, and red top (*Agrostis alba vulgaris*) and many

Fig. 88. Oidium of *Erysiphe graminis* on wild rye (*Elymus robustus*).

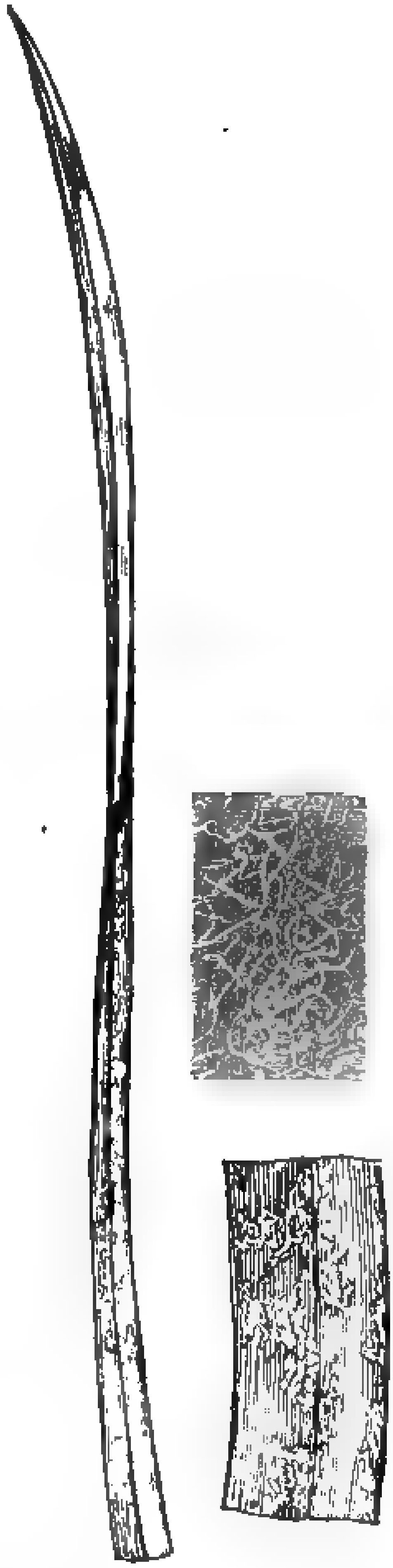


Fig. 89. Powdery mildew of blue grass (*Erysiphe graminis*), leaf of blue grass curled; to the right the leaf more magnified, the black spots perithecia, to the right perithecia more magnified. (King.)

Fig. 90. Powdery mildew of bluegrass, *Erysiphe graminis*, Oidium stage. The leaf to the right hand magnified, the one to the left more magnified, showing the powdery substance.

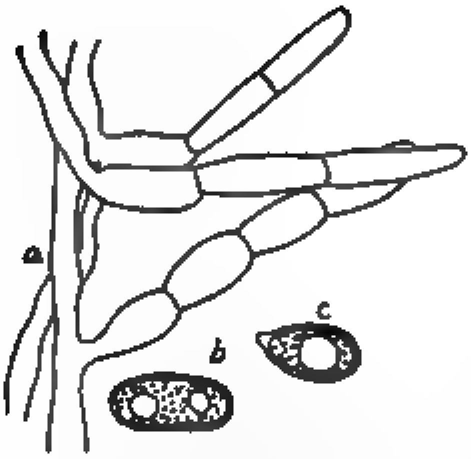


Fig. 90A—a, mycelium and erect conidiophores; b, c, conidia.

of the grasses when grown in moist, shady places, and becoming rank, suffer from this disease From this it would seem that proper drainage would alleviate the trouble. In England wheat is commonly affected and greatly injured. In moist and shady places in this country it is affected. Eriksson reports the fungus severe on wheat at Stockholm, Sweden. Barley and oats are also affected. Von Thumen* states that the fungus is abundant on *Lolium perenne* and *Dactylis glomerata*. The writer has observed it abundantly on several species of Poa, especially *Poa wolfii*, near Golden, Colorado.

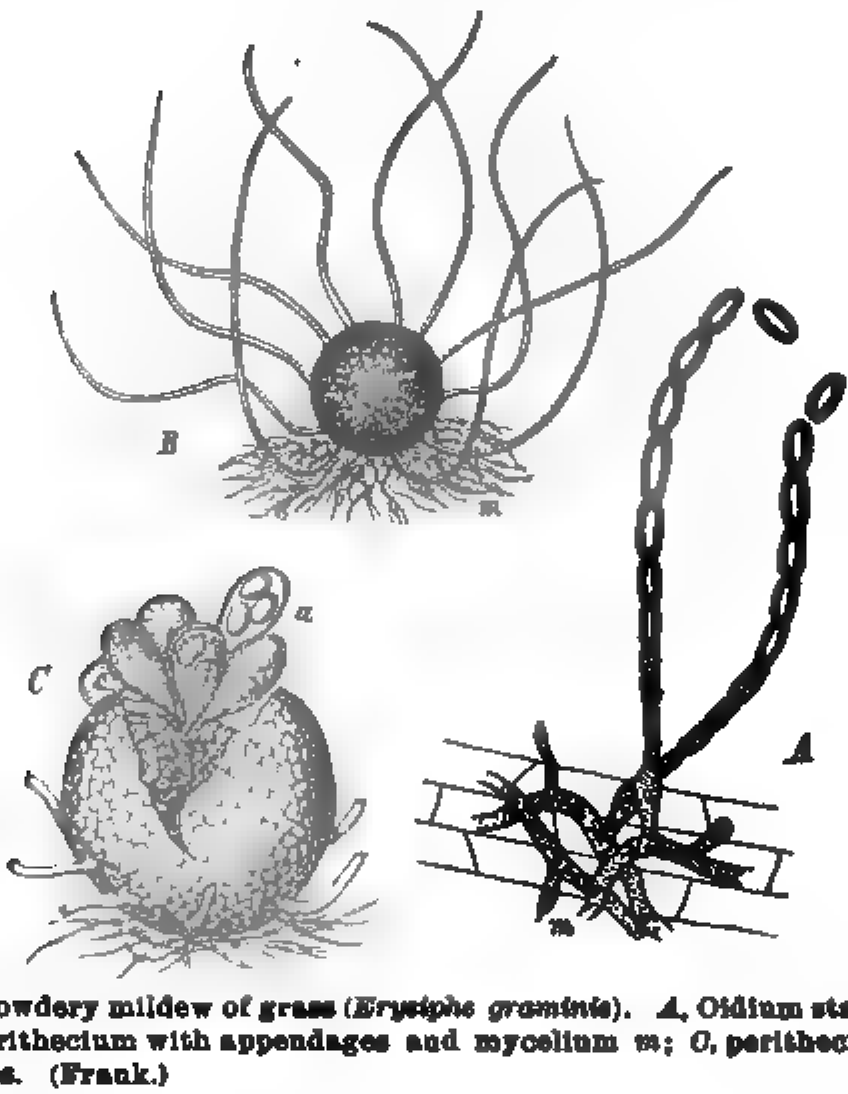


Fig. 91. Powdery mildew of grass (*Erysiphe graminis*). *A*, Oidium stage and mycelium *m*; *B*, perithecium with appendages and mycelium *m*; *C*, perithecium with asci and ascospores. (Frank.)

*Bekampfung d. Pilzkrankheiten. 39.

GIBBELLINA CEREALIS, PASS.

Passerini,* who described this fungus in 1886, states that it was very destructive. Later Cavara† published an extended account of the fungus and has given us the details of its life history. Loverdo‡ likewise describes it. The culm of affected plants is very weak and does not produce fruit. The culm above the first node above the ground shows a grayish-brown circular spot. Later these spots lengthen and become confluent. The spots are covered with a mouldy mycelium which

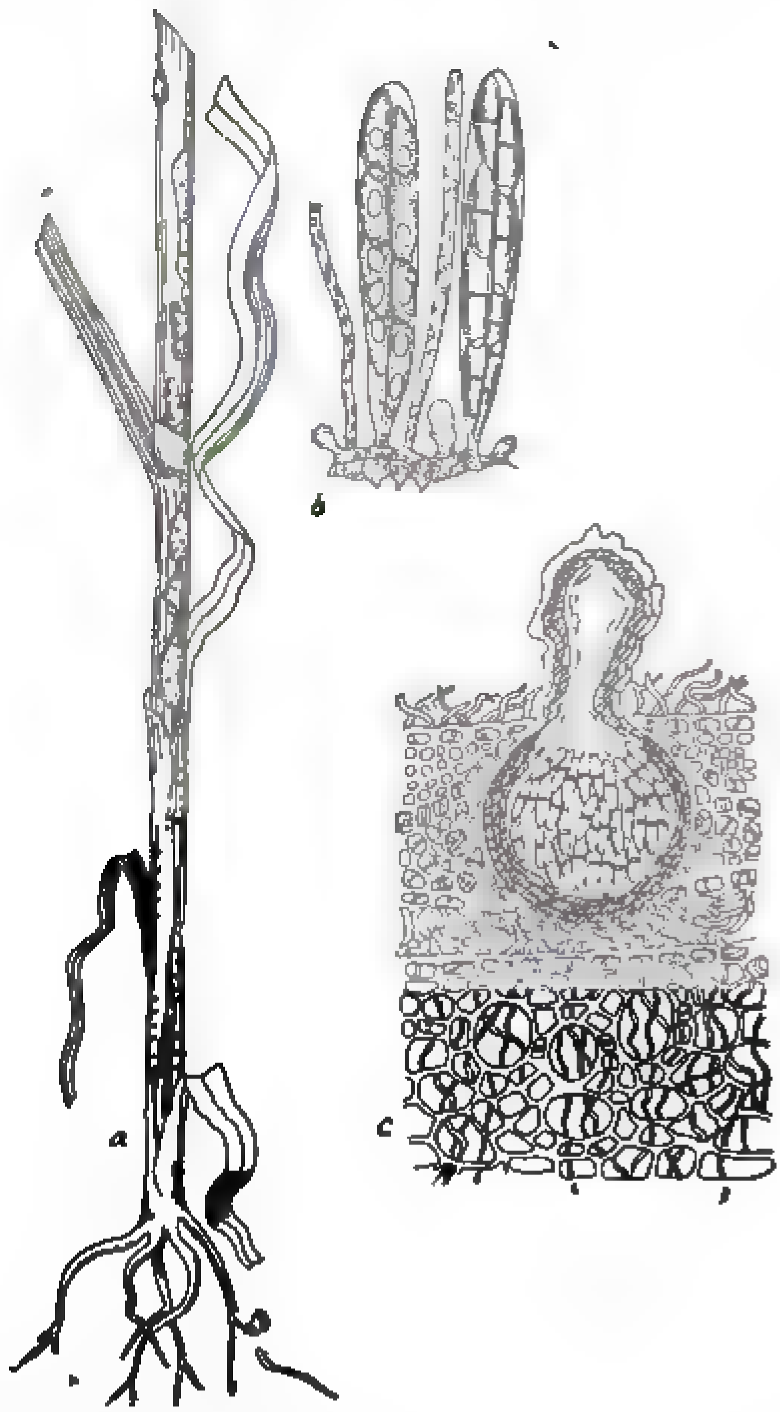


Fig. 92. Stem blight, *Gibbellina cerealis*; *a*, general appearance; *b*, asci with asco-pores and paraphyses; *c*, stroma, mycelium and perithecium. (Cavara.)

*Bol. de Comiz. Agr. Parm. 1886:
†Ueber einige parasitische Pilze. Zeit. f. Pflanzenkr. 3. 16.
‡Les Maladies. Crypt. 25.

sometimes nearly encircles the stem. The lower leaves are dead. The mycelium consists of thick, branched, hyaline septate threads, which spread over the surface of the host, sending haustoria into the cells. The erect threads bear oval or ellipsoidal spores after the fashion of an Oidium. These spores propagate the fungus during the summer. Later immersed perithecia are formed, arising from a deep, white stroma. The perithecia consists of somewhat flattened cells. In the interior occur numerous paraphyses and asci. The club-shaped asci contain eight two-celled yellowish-brown ascospores arranged in two rows. The fungus apparently enters the plant through the delicate tissues of the germinating seedling.

BLACK SPOT DISEASE OF GRASSES.

The *Phyllachora graminis* (Pers.) Fuckel occurs on many cultivated and wild grasses; other species occur on clover and other leguminous plants. This parasitic fungus disease cause blackish spots on the lower or both surfaces of the leaf. The fungus causing these black spots on grasses has been called the black spot disease of grass. This was first described by Persoon* as *Sphaeria graminis.* Fuckel† made the correct combination. It is generally so called by mycologists.

During August, and especially later, the coal black spots along the veins are especially prominent; they are considerably

Fig. 93. Black spot disease of grass (*Phyllachora graminis.*) *A*, showing cross-section of leaf through a black mass; *B*, an ascus with spores enlarged. (*A* and *B*, Frank; a after Trelease.)

*Syn. 30. Dothidea graminis. (Pers.) Fr. Sys. V. 867.

†Symb. Myc. 216. Saccardo Syll. Fung. 2: 602. Ellis and Everhart. N. Am. Pyreno. 609 pl. *40. f. 1-4.*

less than one-eighth of an inch in length and width. They occur on both surfaces of the leaf, but are more abundant on the upper. These black spots are composed of a dense mycelium, which in the green leaves bears numerous small spores which serve to propagate the fungus in the summer. In dead leaves small perithecia are found, which contain numerous elongated bodies, the asci within which are found eight small, colorless spores, known as ascospores; these latter carry the fungus over the winter. In Iowa the grasses most commonly affected by this fungus are quack grass (*Agropyron repens*), wild rye (*Elymus robustus*), *Asprella hystrix*, and *Panicum Scribnerianum*. Occasionally this fungus is quite destructive. Frank,* Tubeuf,† Trelease‡ and Pammel have given accounts of this fungus.

BROWN SPOT OF WHEAT HEADS.

The *Phoma hennebrgii*, Kuehn on wheat was first detected by Kuehn.§ Frank‖ has noted it in Germany and Eriksson¶ for Sweden. This fungus causes brown spots on the sterile and flowering glumes In these spots small perithecia occur. These contain small, one-celled conidia. The kernels become spotted and shriveled. Whole fields may be affected. Related to this is the *Phoma lophistomoides*, Sacc., which is a saprophyte, according to Cavara.** The perithecia are small, 60–80^{u} in diameter, with an oblong ostiolum, and are immersed in the tissue. The spores are small and thread-like, rounded at the ends, 8-10^{u} long, .5–.75^{u} wide.

BROWN SPOT DISEASE OF GRASSES.

The *Septoria graminum*, Desm has received the name of "Take-all" in Australia on account of the nature of its destructive work. N. A. Cobb says: "Taking the occurrence in spots, as a starting point, I determined to see whether some other characteristic symptom could not be made out, and in this I was partially rewarded, for I found in the great majority of cases that the plants dried up when young, mysteriously as some farmers said, and left the ground bare or covered with weeds. This will seem old news to farmers and hardly worth as much

*Krankheiten der Pflanzen. 2: 455. *f.* 80. (Ed. 2.)
*Pflanzenkrankheiten. 243.
†In Beal. Grass of N. Am. 1: 424.
‡Fungus Diseases of Iowa Forage Plants. 24.
§Rabenhorst Fung. Europ. 2261.
‖Zeit. f. Pflanzenk. 3: 28.
¶Mitth. d. K. Akad. Stockholm. 1890.
**Ueber eine parasitische Pilze. Zeit. f. Pflanzenk. 3: 23.

attention as I have given it, yet it is not without a reason that I have made so much of it, as will soon be seen. Moreover, I found the wheat in nearly all well attested cases of 'Take-all' to be infested with two fungi, namely, *Cladosporium herbarum* and *Septoria graminum*. Both these fungi have long been known

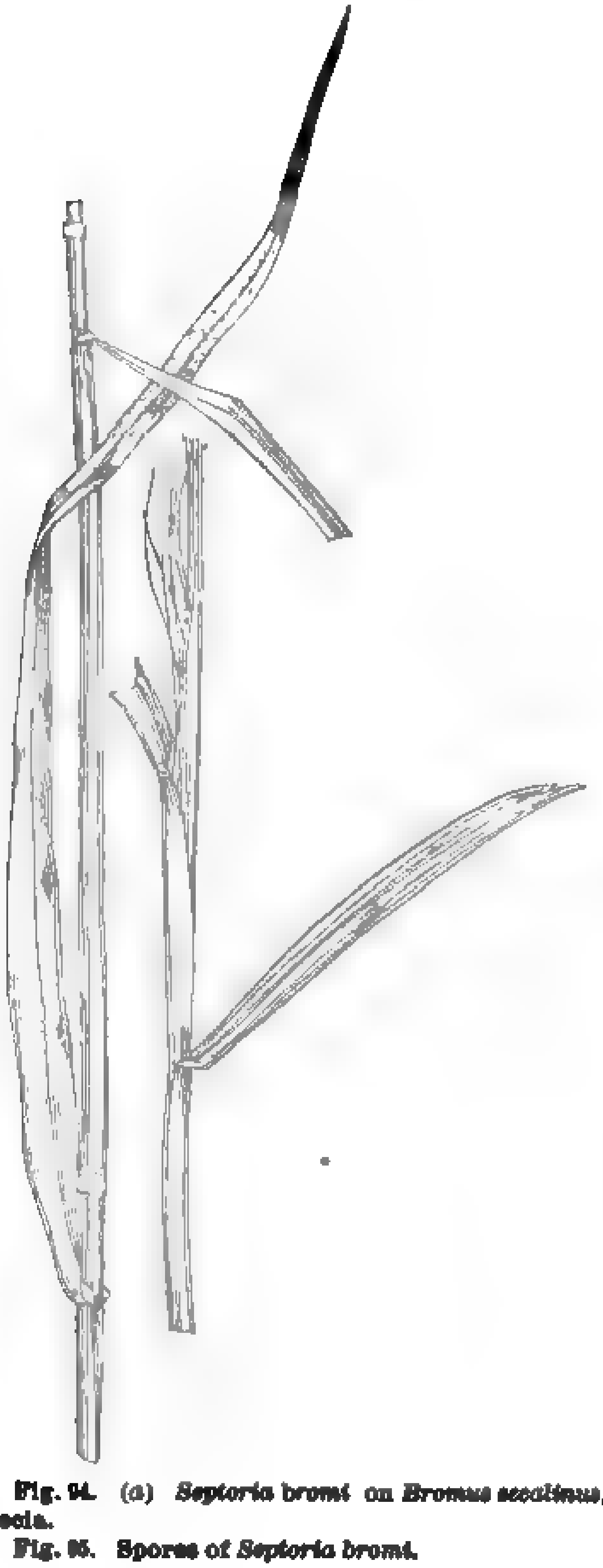


Fig. 94. (*a*) *Septoria bromi* on *Bromus secalinus*, small black spots on leaf the perithecia.

Fig. 95. Spores of *Septoria bromi*.

to botanists, but it is only within recent years, when vegetable pathologists have begun to enquire carefully into the causes of the various diseases of useful plants, that both the Cladosporium and the Septoria have been found to be serious pests in the grainfield."

This fungus disease is common to many grasses and is quite destructive at times. It was described by Desmasier*. It is common, not only in this country but in Europe as well. Eriksson† reports it as common in Sweden and Cavara‡ says it is on the increase in Italy. Cobb§ remarks on its common occurrence in Australia. Trelease‖ discussed it in his work on fungi injurious to grasses and clovers. It is most injurious to wheat and here it causes the young plant to turn a yellowish-green, then becomes yellow. The leaf finally dries and withers. It appears on the sheaths and culms. The interior of the plant contains an abundance of the mycelium. In the dead spots of the leaf may be seen small black specks—the perithecia, which are either aggregated or scattered. These perithecia contain hundreds of small, several-celled spores, 40–50^{u} x 1–15^{u}. They are said by Cavara not to be divided. The spores are, however, occasionally two celled.

In a somewhat extended account of this disease Cobb states that the entire plant is not always involved. It is a variable fungus; its character depending upon the host which it attacks. On *Poa annuus* the leaf is mainly involved and in many cases is totally destroyed. Cavara¶ states that the spots on the leaves are small, elliptical, red or yellow, or the latter may be entirely absent. The injury it does to the young plant is very great; in some cases their total destruction has been observed.

Janczewski** who has studied the life history of *Septoria graminum* states that this represents the pycnidial stage of *Leptosphaeria tritici* and that the conidial form is the *Cladosporium herbarum*.

*Ann. Sci. Nat. Bot. II. 19: 339. 1843.

†Eriksson. On nagra sjukdomar a odlof vaxter samt om atgarder till motarbetande af vaxtsjukdomar. 20.

Tubeuf. Pflanzenkrankheiten. 491. Mangin also states that it is parasitic. See Jour. Roy. Mic. Soc. 1898: 568.

Loverdo. Les maladies crypt. 283.

‡Zeit f. Pflanzenk. 3: 19. Also Briozi. Zeit. f. Pflanzenk. 3: 216.

§Plant diseases and their treatment. Agrl. Gaz. New So. Wales. 3: 991.

‖In Beal Grasses of No. Am. 1: 428.

¶l. c. Zeitsch. f. Pflanzenk. 3: 19.

**Bull. Acad. d. Sc. Cracovie 1892: See Frank Krankheiten. d. Pflanzen. 302. 419. *f.* 63.

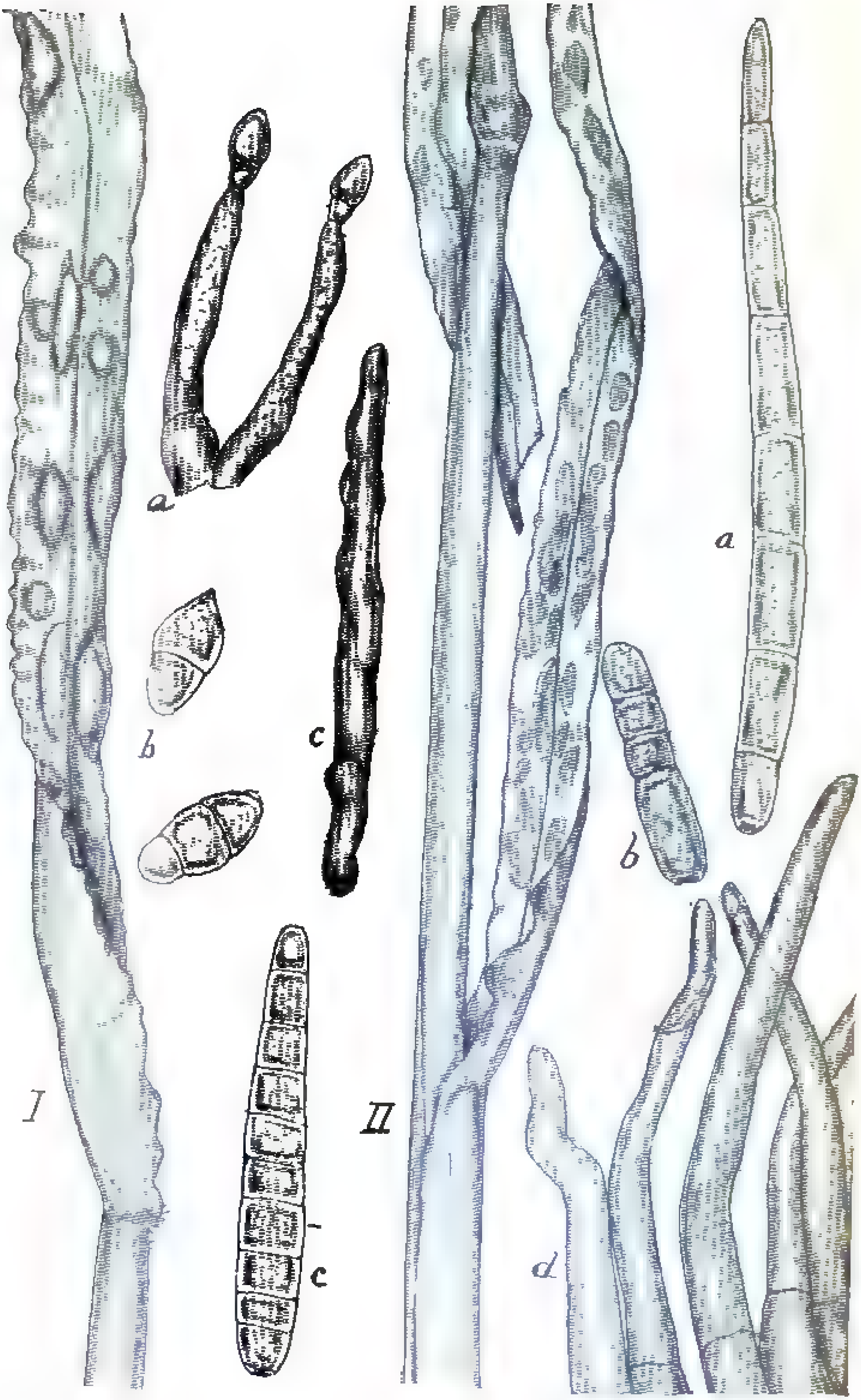


Fig. 96. I. *Cladosporium herbarum* on oats; (*a*) conidiophores and conidia; (*b*) conidia; (*c*) conidiophore. II. Cercospora on barnyard grass; (*a, b, c*) conidia; (*d*) conidiophores. (Pammel and King.)

The *Septoria tritici* Desm. is closely related to the above and should perhaps be regarded as nothing more than a variable form of *S. graminum*. The spots it produces are at first yellow, then reddish-brown, and finally whitish. The spores are 50–60$^{\mu}$ long by 1.5$^{\mu}$ to 2$^{\mu}$ wide and usually divided. A Septoria has been reported on the glumes of wheat in Ohio by Selby.*

Several other species of Septoria are allied to the above species, one, the *Septoria bromi* Sacc. is common in this state on *Bromus secalinus*.

CLADOSPORIUM HERBARUM (PERS.) LINK.

This fungus is destructive in parts of Australia, and has been reported on the increase in Europe by Frank‡, it also occurs in this country as reported by Peck. The writer has likewise observed it on wheat and oats in Iowa. Harvey reported it on oats in Maine. On wheat it is commonly referred to as blight. It attacks all parts of the plant but is especially common in the heads. The mycelium of the fungus grows not only on the surface of the plant but also in the interior. The conidiophores and spores are olive green. The conidiophores pass through the stomata or break through the epidermis. The spores are one to two-celled and are borne on the end or on short lateral branches. The spores are extremely variable in shape and size.

The general effect of the disease is to cause the kernels to shrivel. The disease occurs rather destructively on oats as recorded by Cobb.§ Professor Peck‖ records the occurrence of a Cladosporium on oats, which he describes as a new species, the *Fusicladium destruens*. He says in regard to oats. "The foliage of the plants presented a singular admixture of green, dead-brown and reddish hues, strongly suggestive of that of a 'rust-struck' field." Peck thinks this fungus inhabits the leaves of some of our northern grasses and has escaped from them to oat fields. Mr. F. C. Stewart made a study of Cladosporium while at Ames, finding it on many wild grasses, especially blue grass. Giltay¶ reports that plants are infected in the same way as in some of the grain smuts, the spores being carried

*Bull. Ohio Agrl. Exp. Sta. 97: 42.

†Cobb. 3: 991.

‡Ueber die Befallung durch Cladosporium und Phoma. Zeit. f. Pflanzenk. 3: 28. Rep. Maine State Coll. 1894; 96. *f. 3.*

§Cobb. 3: 1000.

‖Rep. N. Y. State Mus. of Nat. Hist. 43: 9 *pl. 3. f. 19. 22.* 1890.

¶Ueber die Schwarze des Getreides. Zeit. f. Pflanzenk. 3: 200.

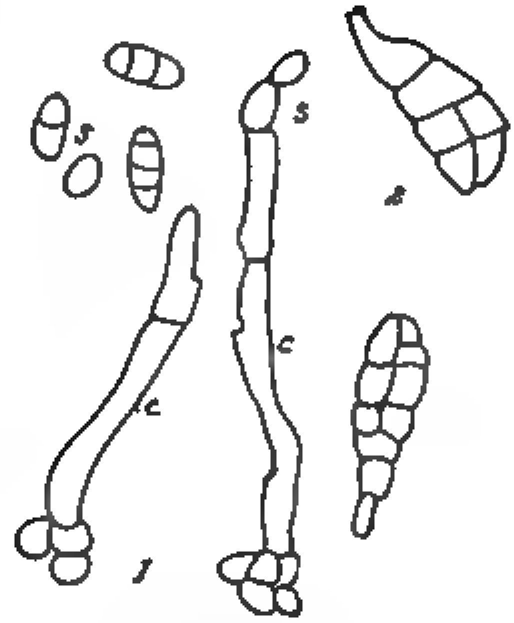
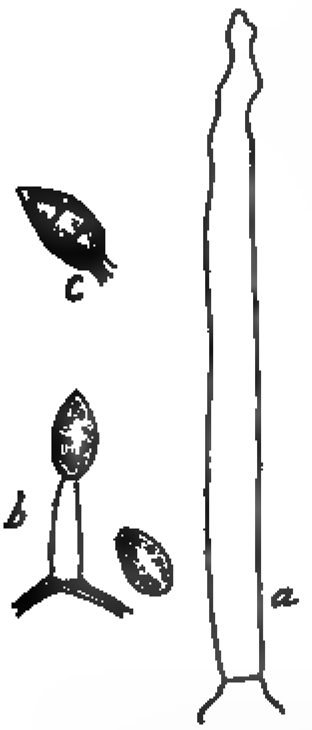


Fig. 97. Cladosporium and other fungi on kernels of corn. Kernels of corn injured on top.
Fig. 97A. Cladosporium-like fungus. S, spores; c. conidiophores; 2, Macrosporium.



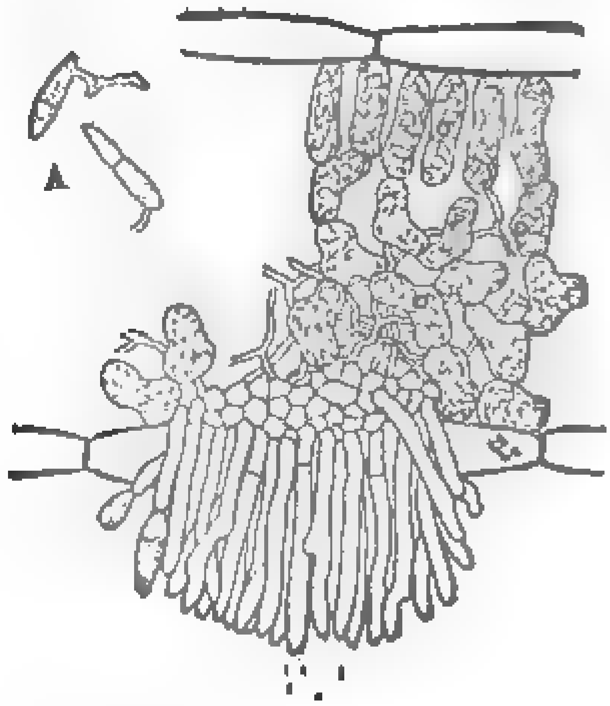


Fig. 97B. Cladosporium Zeae from corn kernels; a, conidiophores; b, c, spores.
Fig. 98. Spot Disease of Orchard Grass (*Scolecotrichum graminum*) Cross-section of leaf, general fruiting layer of fungus with conidiophores and conidia; A, spores germinating (Trelease).

over by the fruits, and that the disease can be prevented by treatment with hot water. A species of Cladosporium commonly affects the kernels of maize, at times quite troublesome. According to Peck the *C. Zeae* Pk. is parasitic and attacks the unripened grasses.

SPOT DISEASE OF ORCHARD GRASS.

Of the many imperfect fungi which attack grasses, one of the most serious is the spot disease (*Scolecotrichum graminis*),

described by Fuckel.* The only extended economic account was made by Trelease,† in 1886 There are also shorter accounts by the writer.‡ This fungus is especially common on orchard grass. It is reported as destructive on timothy and oats by Eriksson.§ It also occurs on timothy and at times is quite destructive. It produces what is sometimes called rust. The writer has also found it on barley. Tubeuf‖ reports it on oats. It has, however, never been noticed on this host in Iowa. Trelease,† describing the occurrence of the fungus about Madison, Wis., says: "When the basal leaves of orchard grass had reached their full length, my attention was attracted by a very abundant discoloration of this species, sometimes confined to the extremity of the leaves, sometimes extending nearly to their base. So far as my observations went, nearly every stool of orchard grass was affected."

The first indication of the fungus is an elongated brown or purplish-brown spot. In older specimens the centers of these spots are gray or whitish and contain minute black dots. These small dark spots contain the tufts of brown fungus threads, which make their way out through the stomata. These fruiting hyphae bear small, smoky-brown, two-celled spores. The fungus causes the cells of the leaf to become much altered, because the colorless threads of the fungus permeate them. The hyphae are sometimes septate and the spores are usually borne at the end or occasioally in a lateral position. On barley the disease is marked by brown or purplish-brown spots which appear on the leaf transversely. Trelease notes that the season of 1886 was a very dry one, very little rain having fallen for several months.

YELLOW LEAF DISEASE OF BARLEY.

The yellow leaf disease (*Helminthosporium graminum*, Rabh) is one of the most destructive of the parasitic diseases affecting barley in Iowa. The fungus has been known for a considerable length of time in Europe, where it was first described by

*Symb. 107. Saccordo. Syll. Fung. 4: 348.
†Beal. Grasses of North Am. 1:428.
†U. S. Dept. Agrl. Rep. 1886: 129.
‡Pammel: Fungus Diseases of Iowa Forage Plants.
‡Pammel: New Fungus Diseases in Iowa. Jour. Myc. 7: 96.
§Bidrag till kannedomen om vara odlade vaxters sjukdomar. 185. *pl.* 9.
§Sorauer. Just. Bot. Jahresb. 1885: 502.
‖l. c. Pflanzenkrankheiten. 526.

Rabenhorst and found by Caspary.* The writer has published several notes on this fungus.† It is closely allied to several species of Helminthosporium. Mr. Ellis, to whom specimens were submitted, writes that the fungus is, without doubt, Rabenhorst's *Helminthosporium graminum* and this is the same as *H. inconspicuum*,‡ C. & E. and Passerini's *H. turcicum*.§ The specimens in Ellis North American fungi were found on dead leaves of *Zea mays*. Passerini's specimens were also found on the species and he attributed it to the fungus he has described. Briosi and Cavara‖ have described, figured, and distributed the same fungus in their collection of parasitic fungi. The spores of these species seem to agree well enough with Rabenhorst's *H. graminum*,¶ which was found by Caspary on barley. Frank**, in his earlier work on the parasitic diseases of plants, considered it to be only a well developed Cladosporium, but later refers it to Helminthosporium. In 1885, Eriksson†† found a disease on barley, near Upsala and Stockholm, which he considered identical with that found by Caspary on barley in Germany. Kirchner‡‡ reports it as common in Germany and gives a good account. Later Aderhold§§ reported on its common and destructive occurrence in Silesia.

The Iowa barley disease agrees with Eriksson's, but differs from the corn disease found by Passerini. According to the latter observer the leaves of corn affected by the fungus are at first yellow, then become more or less discolored and finally wilt.

The spots in the specimens distributed by Briosi and Cavara on corn are sharply limited and extend across the veins. This disease manifests itself long before the barley has headed out. In the barley disease the spots extend from the base to the very tip of the leaf in parallel rows. The diseased leaves form quite a contrast to those of adjoining healthy plants, as they are variegated pale yellow and green. All the stalks of a stool

*Herbarium mycologicum. 332.

†Pammel. Fungus diseases of Iowa forage plants. Pammel. Jour. Myc. 7: 96. See also Sorauer. Pflanzenkrankheiten. 348. Tubeuf. Pflanzenkrankheiten. 581.

‡Ellis N. Am. fungi. No. 45. Grevillea. 6: 88.

§La nebbia del granturco. 3. Schroeter. Just Bot. Jahresb. 1878: 184. Comes. Crittogamia agraria. 1: 409.

‖Fungi Parassiti delle piante cultivate od utili essicati deliniati e descritti. Fasc. III and IV, No. 81.

¶Herbarium mycologicum. 332.

**Krankheiten der Pflanzen. 582. (Ed. 1.) 316. (Ed. 2.)

††Ueber eine Blattfleckenkrankheit der Gerste. Bot. Centralbl. 29: 89. Sorauer Just Bot. Jahresb. 1885: 515. Distributed in Fungi Scand. 187.

‡‡Braunfleckigkeit der Gerstenblatter. Zeitsch. fur. Pflanzenk. 1: 24.

§§Zeitsch. fur. Pflanzenk. 5: 10.

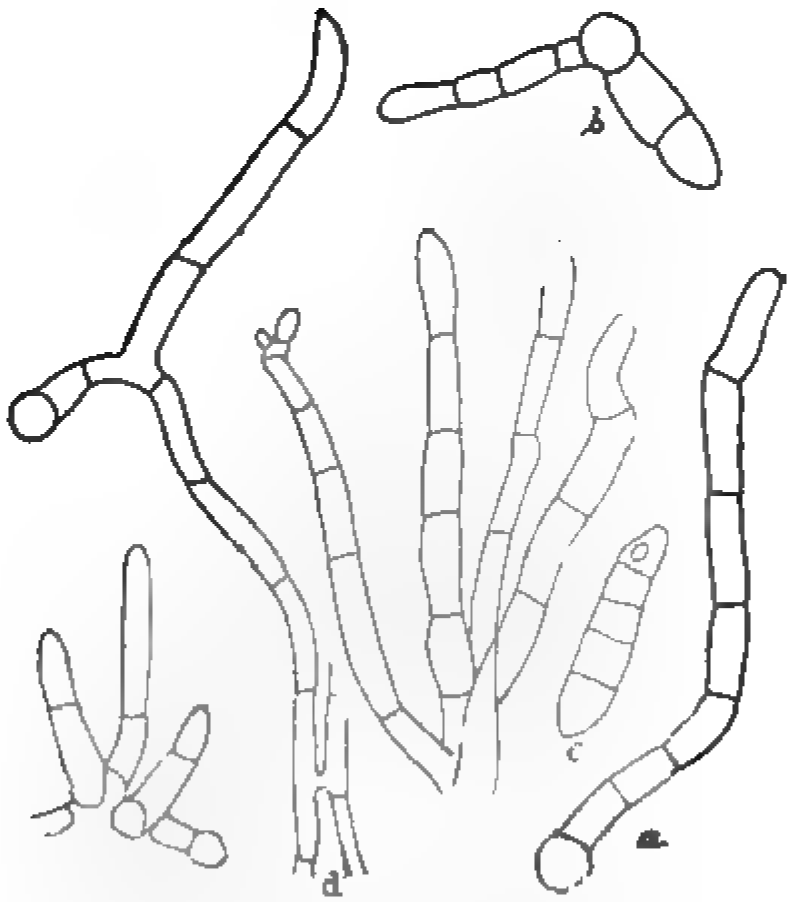
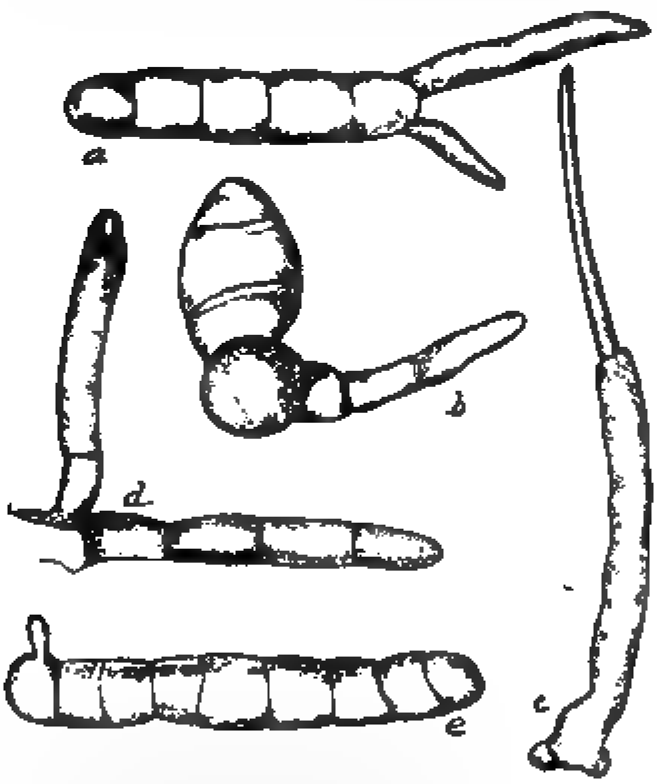


Fig. 99. Yellow leaf disease of barley (*Helminthosporium graminum*, Rabb.) *a*, hypha; *b*, hypha arising from short cells; *c*, conidium, cluster of conidiophores to the left; *d*, mycelium. (Pammel and King.)



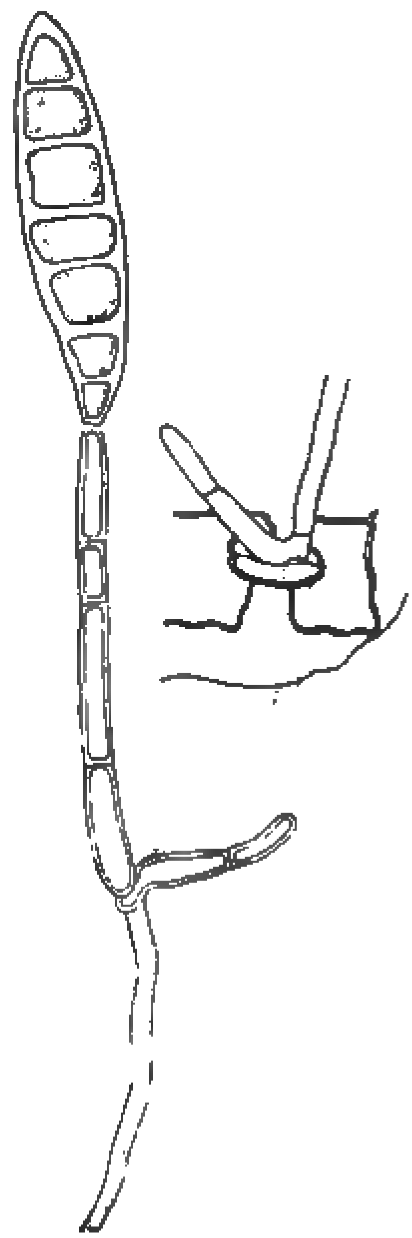


Fig. 100. *Helminthosporium graminum*; *a*, spore germinating; *d*, conidiophore; *b*, conidiophore; *e*, conidium or spore.

Fig. 101. Leaf browning of corn (*Helminthosporium turcicum*) to the right. Mycelium below and a seven-celled spore above. Condiophore pushing through the stoma in right-hand figure. (Pammel and King.)

are affected. The plants die prematurely, and soon after death the leaves become torn into shreds. An examination of the affected parts when the variegated linear stripes appear shows a colorless mycelium permeating the tissues of the leaf. In older parts of the leaf blackish masses are clearly made out with the naked eye. These masses consist of the spores and fruiting fungus threads. The erect septate hyphae make their way through the opening of the stoma or break through the epidermis, bearing large three to six-celled spores at the end. Occasionlly one finds these hyphae branched. The mass of brown hyphae and spores along the veins can be seen easily with the naked eye. The spores germinate readily, often a number of germinating tubes coming from a single spore. The *Helminthosporium teres*, Sacc., on oats, described by Briosi and Cavara, is closely allied to the above species. The mycelium is intercellular and causes elongated dead spots, finally death of the leaf.

LEAF BROWNING OF CORN (HELMINTHOSPORIUM TURCICUM, PASS.)

Spot diseases are abundant and destructive on many of our cultivated plants. Corn, so far, has been unusually free from these troublesome diseases. In 1876, Passerini,* an Italian mycologist, described a fungus, *Helminthosporium turcicum*, as occurring on living leaves of corn. It was distributed by Rabenhorst.†

Earlier, Cooke and Ellis‡ described a somewhat similar Helminthosporium, the *H. inconspicuum*, on dead leaves of corn. The Cooke and Ellis species is sometimes parasitic. Comes§ holds that this fungus is distinct, although closely related to the European. Peck‖ states that it occurs on living or languishing leaves of Indian corn, and Harvey reports the var. *britanicum*, Grove on oats. Professor Peck gives the following account of the disease: "If the lower leaves of corn stalks be examined toward the end of summer, some of them will be found to be dead and discolored at and near the pointed end. This discoloration is sometimes continuous, involving the whole

*La Nebbia del gran turco. Parma. 1876. Abst. J. Schroeter. Just. Bot. Jahr. Just. 1876: 184.

†Fung. Europ. 23.

‡Saccardo. Syll. Fung. 4: 411. Grevillea. 6. 88. Ellis. N. Am. Fung. No. 45.

§Crittogamia Agraria. 409.

‖Ann. Rep. State Mus. Nat. Hist. N. Y. 34: 51. 456. *pl. 3. b.*

¶Ann. Rep. Maine State Coll. 1894: 21. 95.

outer half of the leaf, and sometimes is interrupted and forms spots of various sizes and shapes. The spots, by increasing in size, become confluent, and thus a leaf, at first spotted, may soon become uniformly discolored. The discoloration results from the death of the leaf tissues and the destruction of the green coloring matter of the leaf cells, the affected parts appearing to the observer like so much dead leaf."

Stewart* states that the *H. inconspicuum* on Long Island must be regarded as an enemy of considerable importance. Both sweet and field corn suffered in some cases so severely as to materially lessen their value for fodder. The farmers attributed the cause of the disease to a period of unusually hot weather which prevailed during the month of August. Thaxter† states that it is also injurious at times in Connecticut where it is known as "white blast of Indian corn." It is common at times in Iowa and does much injury.

Later Briosi and Cavara distributed a fungus on corn with a description of Passerini's *H. turcicum*. In 1891 one of us gave an account of *Helminthosporium graminum*, Rabh., on barley in which reference was made to the fungus on corn. J. B. Ellis, to whom the fungus was submitted states that it is identical with the corn fungus. After a careful examination of the material at hand we are of the opinion that these fungi are different. The Italian fungus has not been observed here, but an account is given to complete the list of diseases occurring on corn. In the Italian disease the spots are sharply limited across the veins, one to three inches long, one-sixteenth to one-eighth of an inch wide. The dead tissues have the appearance of dead corn leaves when ripe or affected by frost and produce premature wilting. The surrounding green is in strong contrast. Over the dead areas may be seen small brown clusters, the hyphae and spores.

One or more of the fruiting hyphae make their way through the opening of the stoma. These come from a colorless mycelium. The conidiophores as well as the spores are brown. The latter are large, 8–100^{u} in length, 20–24^{u} in width. This fungus is often associated with *Cladosporium fasciculatum* Corda

*Rep. Geneva N. Y. Agrl. Exp. Sta. 15: 452. *pl.* 32. *f.* 2. 1896.
†Rep. Conn. Agrl. Exp. Sta. 1889: 171. 1890.

and *Alternaria tenuis* Nees. The disease is not limited to corn but also occurs on sorghum (*Andropogon sorghum*).

GRAY SPOT DISEASE (PIRICULARIA GRISEA (COOKE) SACC.)

Crab grass (*Panicum sanguinale*) is seriously affected at times with the above fungus. It is sometimes difficult to find a healthy plant. The affected leaves at first are pale green in color, then become brown. The mycelium occurs in the interior of the leaf; the hyphae protrude through the openings of the stomata, bearing small pear-shaped spores slightly smoky in color. The spores measure 9 x 18^{u}. The affected parts have an ashy gray color.*

WHEAT SCAB (FUSARIUM ROSEUM, LINK).

This fungus as an enemy of wheat was first described by Worthington G. Smith† as *Fusarium culmorum.* It is probably not common on the continent of Europe, as it is not reported by Loverdo, nor is much said of it by Sorauer. That it is a serious trouble here will be seen from the following estimate in Velvet chaff wheat: Out of a total of 125 heads, 73 were perfect, 24 blighted one-third, 7 entirely blighted, and 24 blighted less than one-third. In the variety John, Mr. Stewart estimated the loss at about one-fifth. In hybrid Dattel, out of 120 heads counted, 57 were perfect, while 8 were entirely, 8 one-half, 15 one-third and 32 partially destroyed. Weed‡ has made this fungus the subject of several papers. He says: "In 1890 I saw a field of 100 acres in Madison county, Ohio, considered the finest wheat field in the county, and which was expected, shortly before harvest, to yield 35 to 40 bushels per acre, so severely attacked by the disease that the yield was reduced to 8 bushels per acre. Two other fields, one of 25, the other of 50 acres, were shrunken in yield at least one-third from the same cause. The fungus apparently gains access to the tender, undeveloped kernel, sapping its life and sending down feeders into the main axis of the head on which the kernel and enclosed chaff are borne."

*Saccardo. Syll. Fung. 4: 217. *Trichothecium griseum* Cooke Rav. Amer. Fung. 580.

†Diseases of Field and Garden Crops. 208. This fungus is placed with Endoconidium by Prillieux and Delacroix.

‡Soc. Prom. Agrl. Science. 11: 47. *f. 1*, Fungi and fungicides. 199. See also Pammel. Jour. Mycology. 7: 97.

The disease appears about the time when the grain begins to turn. Either the entire head or some part of it ripens suddenly and prematurely. If the head is partially destroyed the lower part will be green. Affected heads or parts of the same have a whitish appearance instead of a golden yellow. The

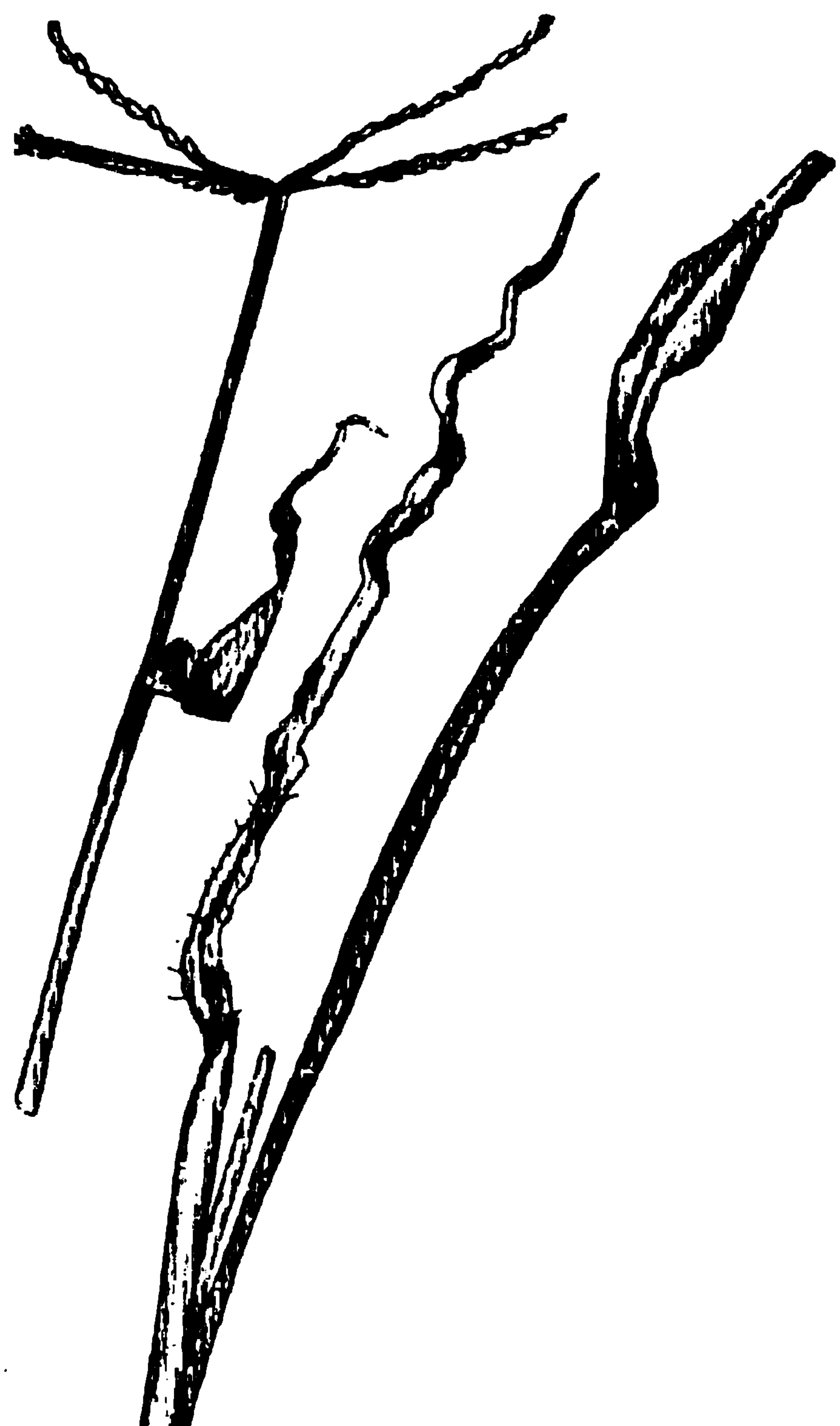


Fig. 102. Gray spot disease of crab grass (*Piricularia grisea*). (King.)

disease usually starts at the upper end, although it may begin at the lower end. The mycelium is whitish or varies from yellow to orange, divided, torulose. The spores are borne on erect threads arising from the mycelium, terminal or lateral, crescent-shaped, at first one-celled, finally divided into two or more cells. The color of the spores is whitish or, in masses, orange or pink. In germination each cell produces a germ tube. The several-celled spores may break up into conidia.

The *Fusarium heterosporum* Nees, is common in parts of Germany, and Tubeuf quotes Frank as stating that the destruc-

tion of rye is total in some places, the fungus investing the whole kernel. Rostrup* mentions it as destructive to germinating barley. It also occurs upon ergotized rye and is regarded by some mycologists as distinct from *Fusarium culmorum.* It is probable that the various species of Fusarium

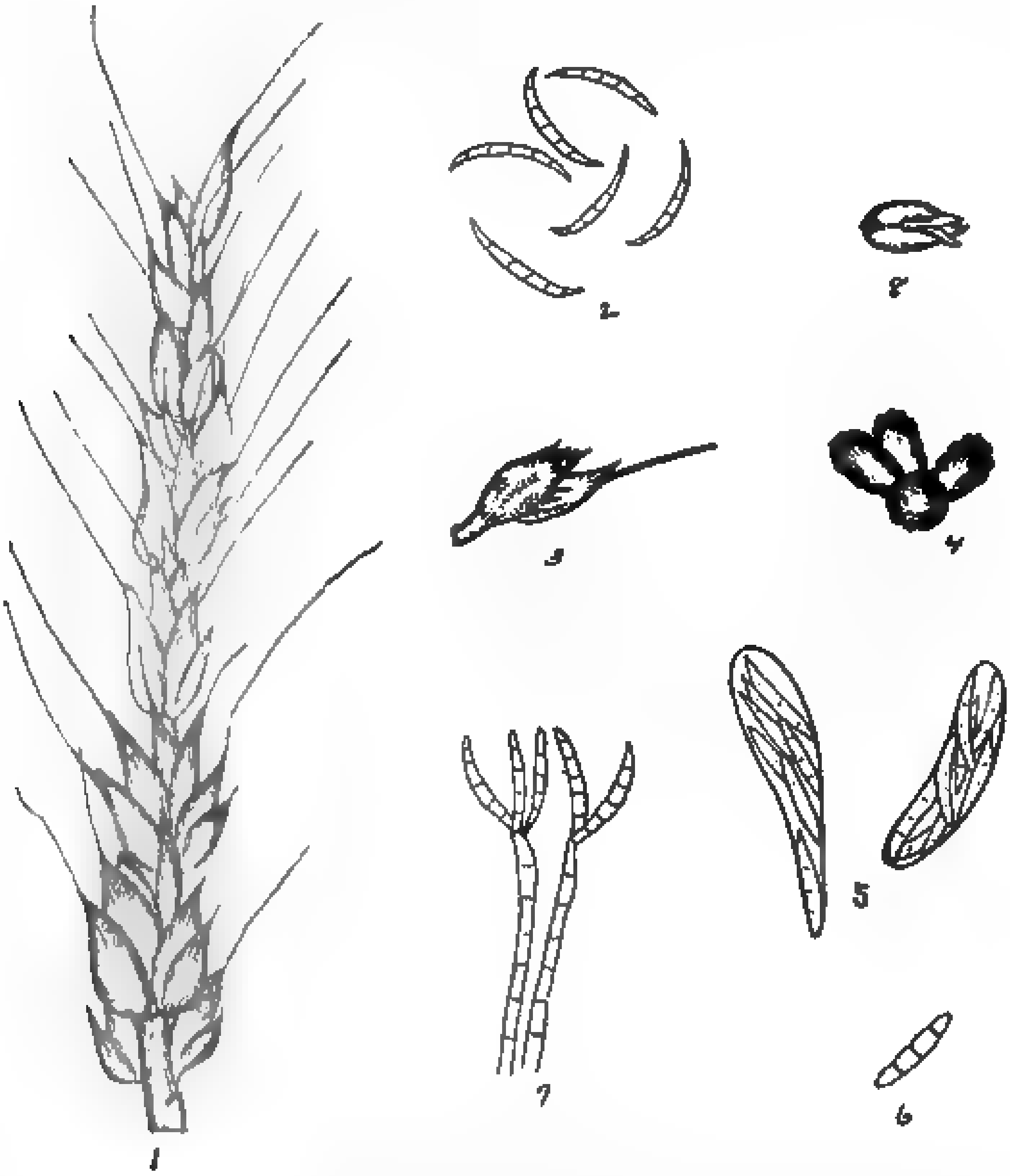


Fig. 108. Wheat scab (Fusarium roseum or, *Gibberella saubinetii* (Mont.) Sacc.). *1*, wheat head affected with wheat scab, upper portion destroyed; *2*, spores of Fusarium; *3*, glumes covered with perithecia; 4, perithecia; *5*, asci from perithecia, with ascospores, one of these enlarged at *6*; 7, conidiophore and conidia grown in agar. (After Selby, Ohio Agrl. Exp. Sta.).

infesting cereals should be referred to *F. roseum*, Link,† and according to Saccardo‡, the ascigerous stage is *Gibberella saubinettii* (Mont.) Sacc. Selby§ agrees with Saccardo in regard to its genetic connection with Gibberella.

*I. 538.

†Frank. Krankheiten der Pflanzen 358. (Ed. 2.) 1896.

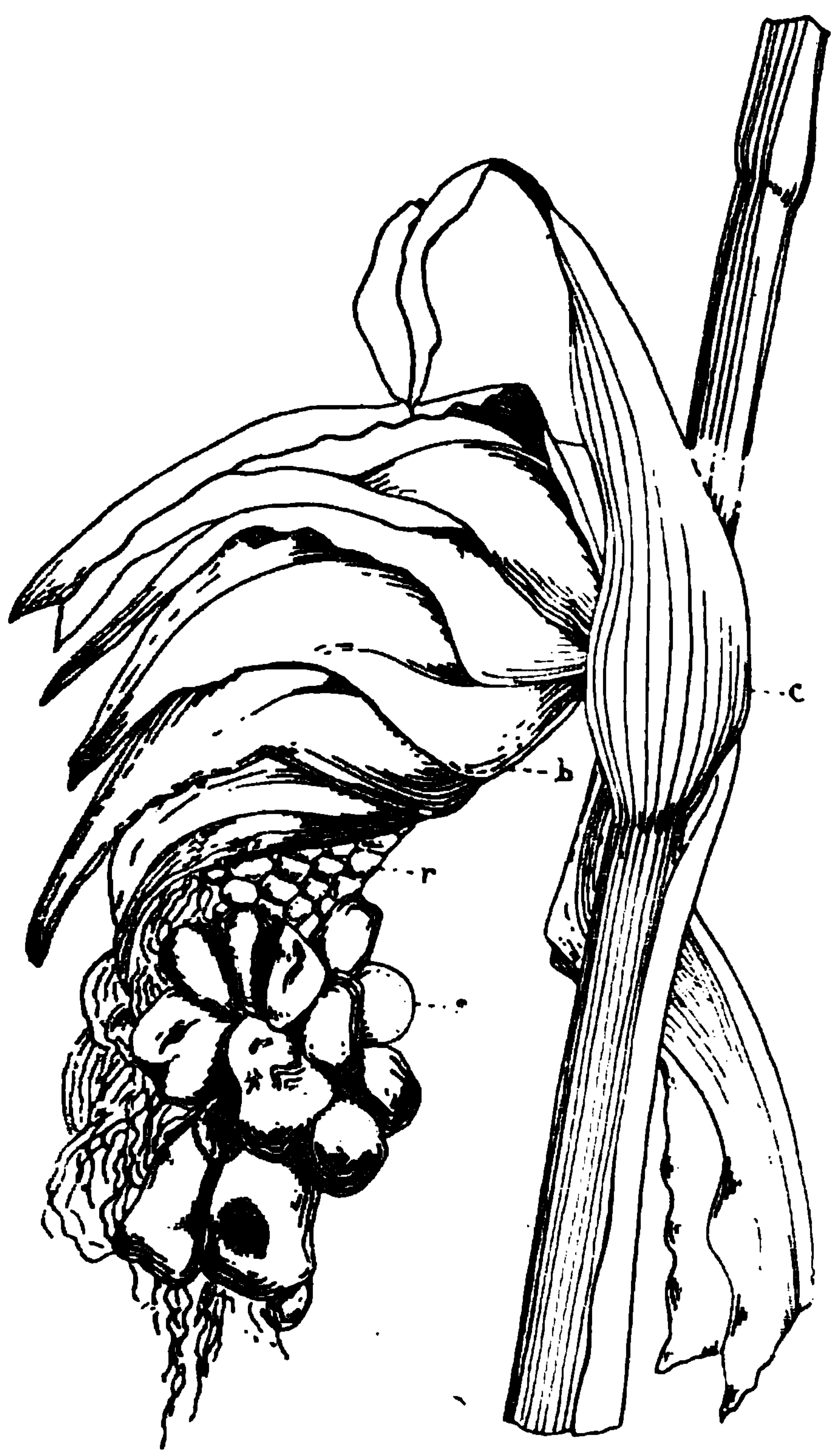
‡Syll. Fung. 2: 554.

§Bull. Ohio Agrl. Exp. Sta. 97: 40.

SMUTS—USTILAGINEÆ.

The Ustilagineæ are popularly known as smuts and are well known to all farmers, at least those affecting our cereal grasses. Among the several hundred species those of cereals are most destructive, entailing a loss to the farmer every year of millions of dollars.

A large number of the economic grasses are likewise affected, but these are not so often observed, though the loss in many cases is quite serious. I have not attempted to discuss all of the smuts of our economic grasses, though I have given short accounts of the more important, and especially the smuts of cereals. Many important studies have been made in this country especially of our economic species. Kellerman and Swingle, Arthur and other mycologists have made important contributions to our knowledge of Ustilagineæ. I have freely



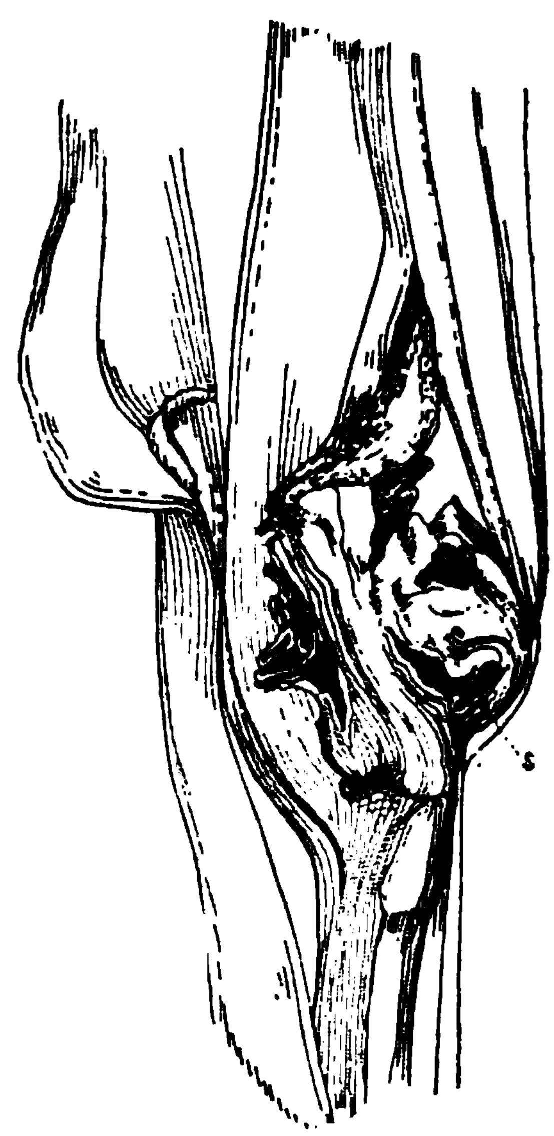


Fig. 104. Maize smut, *Ustilago maydis*. Ear affected, *e*, smut boils; *r*, kernels; *c*, bracts.

Fig. 105. Smut boil making its appearance at the node. (King.)

used their material with such work as has been done from ti to time during my connection with this experiment station.

CORN SMUT (USTILAGO MAYDIS). D C.

For more than a century this troublesome fungus dise has been known. The first reference to it was made by Aym in 1760, who records the disease on the tassel of corn. In 1 it was described by De Candolle† as *Uredo segetum.* Var. *ma zeae.* D. C. Burger,‡ in his work on corn, gives a sh account of the fungus. Bonafous,§ in his treatise on corn, gi the most complete of the early accounts of this dise Kuehn,‖ Tulasne,¶ Meyen, **Brefeld, ††Fischer de Waldhei and a host of other writers have contributed to an accoun corn. For a good bibliography as well as abstracts and c clusions of these writers we must refer to a paper by Hitchc and Norton.§§ These writers have followed Magnus in ado ing the name of *Ustilago mays zeae* (D. C.) Magnus, but name in common use, that of *Ustilago Maydis*, seems prefera and is adopted in this paper.

General characters.—Corn smut makes its appearance wh the plant is three or four feet high, a little before the time flowering, although in some cases it is not observed till the e form. Careful search will show that many leaves, as well the nodes, are infested before the ear forms. In the leaf, sm wrinkled patches appear. These are frequently reddish color; later assume a glossy white color, and as it becom older changes to a black sooty mass. The lower nodes a especially infested; also where the leaf joins the sheath. T

*Rec. sur. les progres et les causes de la Nielle. 77.

†Fl. Fr. 2: 596.

‡Abhandling uber Mais. 242-43. 1809.

§Historie Naturelle. Agricole et economique du Mais. 94. 1836.

‖Die Krankheiten der Kulturgewachse. 70. 1859.

¶Memoire Sur les Ustilaginees comparees aux Uredinees. Ann. Sci. Nat. I 7: 83. 1847.

**Pflanzen Pathologie. 102. 1841.

††Untersuchungen aus dem Gesammtgebiete der Mykologie. Also Neue Unt suchungen uber die Braadpilze und Brandkrankheiten. II Nachrichten aus d Klub der Landwirthe zu Berlin. 1888.

‡‡Contr. to the biology and history of the development of the Ustilagineae. Re N. Y. Agrl. Soc. 1870: 280. Translated from Pringsh. Jahrb. Wiss. Bot. 7: 61.

§§Bull. Kans. Agrl. Exp. Sta. 62. 190-197. 1896. See, also, Corda. For contrib tions to the knowledge of the different kinds of brands in the cereals and blight grains, by Corda, translated by Smith, 19. *pl. 3 f. 1-2.* Emmons' Agrl. of N. Y. 2: 2

sheaths, leaves and stems are more frequently attacked than the ears, as is shown elsewhere in this paper. The staminate flowers or tassels are especially affected, either a few of the spikelets or a large number, or a very distinct boil makes its appearance below the staminate flowers on the stem.

The most characteristic appearance of the smut occurs in the ear, forming the so-called boils. This may include the whole ear or only a small part. The smaller ears further down are affected later, in part by auto-infection or from spores contained in the field.

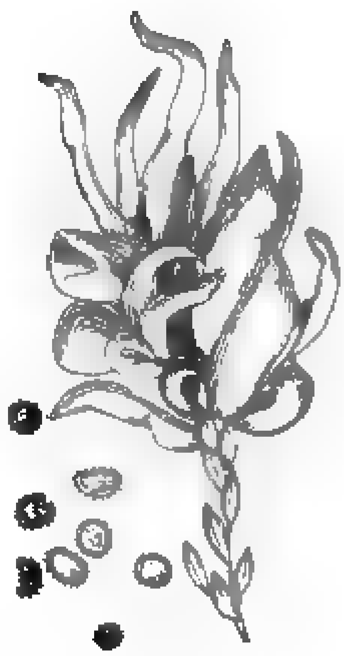


Fig. 106. Maize smut on leaf. S—Smut boil, leaf very much wrinkled. The black smut boils contain the spores. (King.)

Fig. 107. Tassel showing corn smut boils and spores. (King.)

Microscopic characters.—The sooty mass consists of a large number of small bodies known as spores, that serve for the reproduction of the fungus. These spores are usually round, spherical, somewhat spiny and measure about $\frac{1}{2500}$ (8–13 x 8–11μ) inch in diameter. Hitchcock* has given the measurement of a large number of spores. Under proper conditions of moisture these spores germinate. This proceeds best in sterilized rain-water and if kept under proper conditions of warmth, a tube emerges through a pore. The spore consists of an outer wall, which is spiny, and an inner more delicate, the endospore. The tube or promycelium, as it is called, normally bears lateral

*Hitchcock. Variation in spores of corn smut. Science 22: 333.

bodies, the conidia, but under more favorable conditions of food these may branch and bear secondary conidia. If the nutrient material is not exhausted this process of budding may be continued for a long time. These spores may propagate in a decoction of manure. It will then be seen that these budding conidia may be a center of infection.

The conidia as well as the secondary conidia are blown about by the wind and under proper conditions cause the infection of the corn plant. Several years ago Mr. F. C. Stewart* made some extended studies of the germination of corn smut in which it was shown that the thermal death point of smut spores is 15 min., 105°–106° C. in dry oven, and 52° C. when immersed in water; and that corn is unable to come through an inch of soil after 15 minutes treatment with water at 70.5° C., and in dry oven at 78° C. Brefeld† found that smut spores produced an abundance of secondary conidia when they were germinated in sugar solution, but with us this has never been a very satisfactory method of propogating them as the cultures soon became infected with bacteria which materially checked the progress of the germination of spores. These bacteria came from the smut.

Age has something to do with the germination of the spores. In our own work fresh spores never germinated as well as those perfectly dry. Those of a previous season always germinated well. They may preserve their vitality for a considerable length of time. Brefeld has shown that spores 2 years old germinated readily, and that spores 7 years old germinated in nutrient solution in from five to eight days.

Norton and Hitchcock, however, found that the young spores just formed germinate best, and grow more vigorously after germination. Brefeld, however, found that old spores when germinated will grow as vigorously as the newer.

Manner of infection.—Until the exhaustive researches of Brefeld, the statement of Kuehn,‡ an excellent observer and investigator were accepted. Kuehn stated that the mycelium from the germinating spores enters at the root node, the most tender part of the corn plant, as in the case of wheat bunt. He supposed this to be true of other smuts as well. It has been

*Effects of heat on the germination of corn and smut. Iowa Acad. Sci 2: 74-78. 1894.

†Untersuchungen aus dem Gesammtgebiete der Mykologie. Ueber Hefenpilze, V Heft. 67-76. 1883.

‡Bot. Zeit. 33: 122.

Fig. 108 Maize smut spores germinating in sugar solution. (Brefeld U. S. Dept. Agr.)

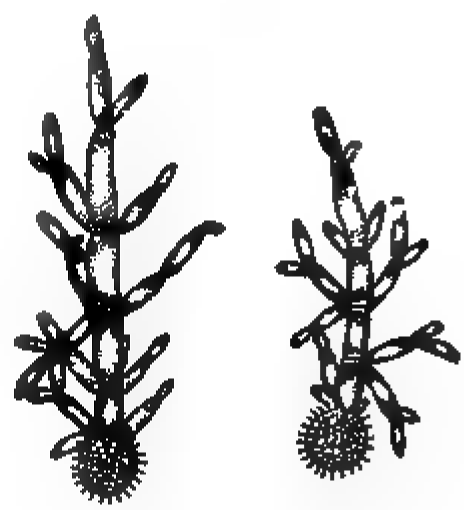


Fig. 110. Maize smut germinating in water. (Brefeld U. S. Dept. Agr.)

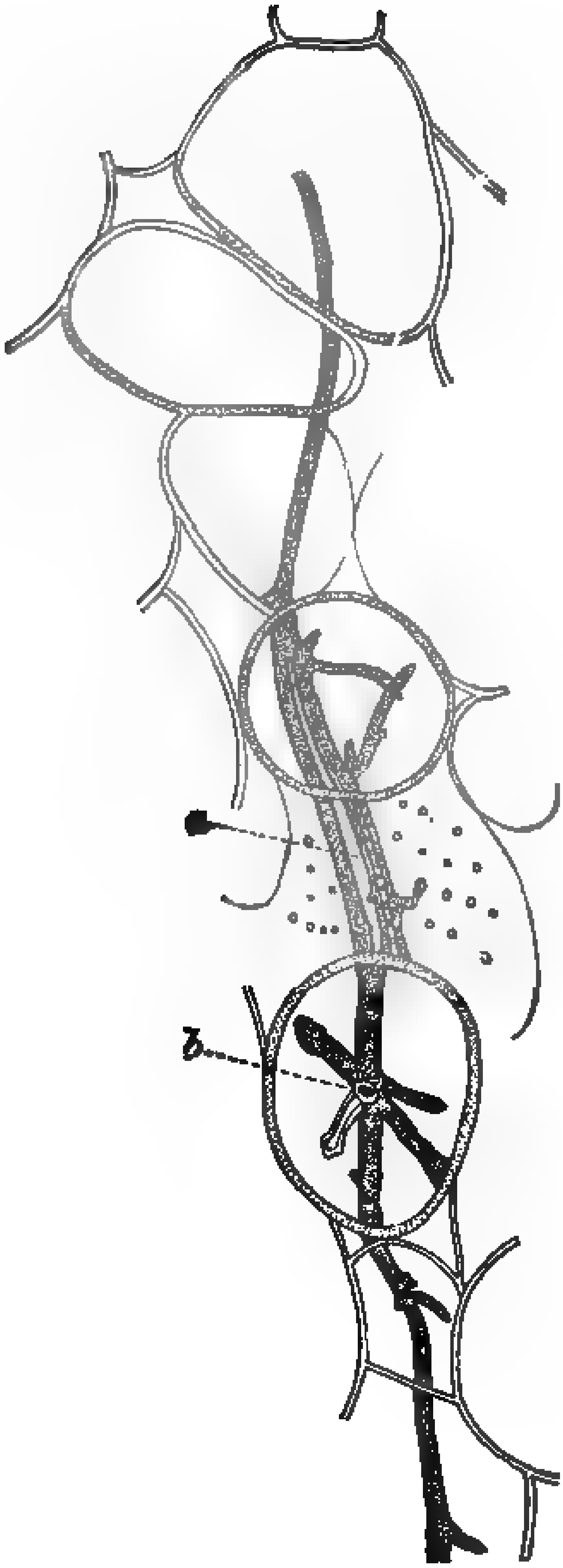


Fig. 109. Maize smut (*Ustilago maydis*); a, mycelium of fungus and cells of the host. (U. S. Dept. of Agrl.)

shown that Kuehn was in error, at least for some of our smuts. Because, however, of Kuehn's work, it was recommended to treat seed corn as wheat seed was treated for bunt. In 1892 experiments were made at the Iowa Agricultural College* with corn, in which seed was treated with hot water heated up to 53–55° C.; also ammoniacal carbonate of copper, and copper sulphate. The hot water treatment, as the work of Stewart indicated, could not have been effectual, since the smut spores can be heated higher than corn. The other treatment should have been effectual, since the smut spores are sensitive to copper solutions. In all cases there was no appreciable difference between treated and check. Independently of this work, the botanists of the Kansas Experiment Station† made some experiments from which the following conclusions were drawn:

"Further investigation is necessary in order to determine the mode of infection—a point that must be settled before we can hope to employ rational methods for the prevention of this annoying and destructive pest."

More complete experiments made by Hitchcock and Norton‡ indicate that:

1. "Infection may take place at any time of the season when the corn is growing, and does not depend so much on the time of the season as on the stage of development of the plant.

2. "Infection may take place in any part of the plant where growing tissue is present, and at any time in its life, but scarcely ever before the plant has attained the height of three feet.

3. "After the tissues are hardened, the smut cannot penetrate them, and consequently infection does not take place in older parts of the corn, but only in the growing tissues. This growing condition is found in the young leaves when the first smut appears in the field; later it occurs mostly at the junction of the leaf and sheath, where cells are present for a long time in a state of growth, and are consequently exposed longer to penetration by the germ tubes from the conidia; still later this is found in the flowers and young parts of the ear and tassel; while finally the only parts open to infection are the rudimentary ears, which develop after the larger ears, at each joint on the lower part of the stalk.

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*Bull. Iowa Agrl. Exp. Sta. 25. 315. See also Bull. 20. 721.
†Bull. Kansas Agrl. Exp. Sta. 23: 315.
‡Bull. Kansas Agrl. Exp. Sta. 62: 183-187.

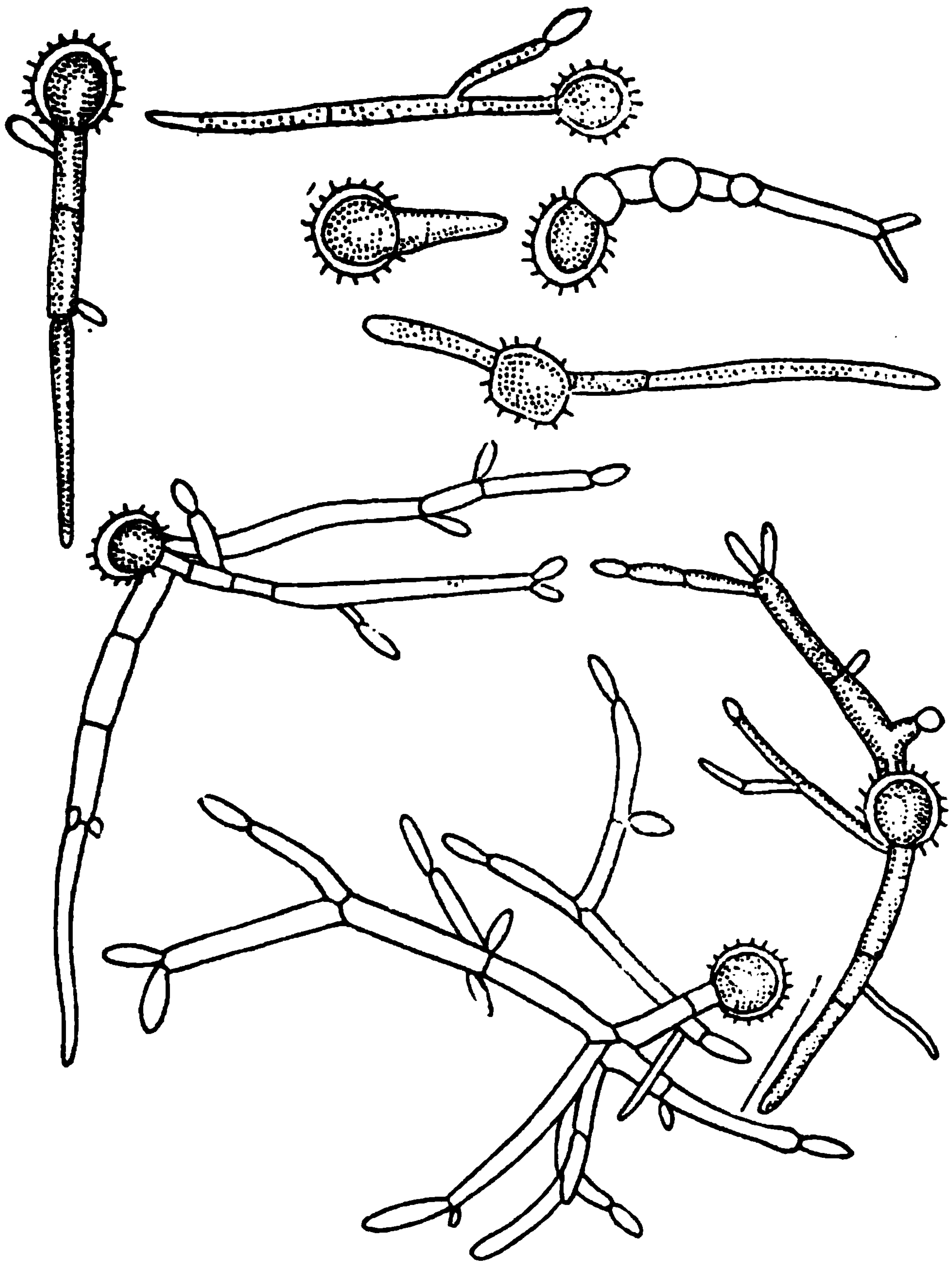

Fig. 109. Corn smut (*Ustilago maydis*) germination of spores in water.

4. "The infection is probably through the conidia and not directly from the spores. Brefeld's investigations, mentioned elsewhere, seem to demonstrate this.

5. "The period of incubation, or time between infection and the appearing of smut boils, is about ten days.

6. "It is probable that the early infections come from the spores of last year, which germinate on the ground at the first favorable weather in the spring, while the later and more abundant infections are from the new spores developed early in the season."

Professor Morini* seems to have established the fact that the passage of spores through the intestinal tract favors the germination and penetration of the sporidia in its host plant.

*Morini. Il. Carbone delle piante Chimica Veterinaria 7: See Loverdo Les Maladies Crypt. 76.

We add here also Brefeld's* conclusion. His experiments are divided into four series from which the following conclusions were drawn. *First.*—Very young seedlings could be infected to a slight extent; older ones not at all. *Second.*—Successful infection in rolled up young leaves, when plants were a foot high. *Third.*—Successful in young inflorescence. *Fourth.*—When brace roots were in right condition they took the disease.

"According to this, the final result of all the infections with corn smut on maize is entirely different from the previously described results with smut fungi living exclusively in the grains. The smut germs come to full development and produce smut pustules and spore beds on every spot of the still undeveloped parts of the plant into which they have penetrated. The action of the germ is narrowly localized—only those parts of the young plant become smutty which have been attacked directly by the fungus germs; all the rest remain normal and sound. The formation of the smut pustules begins quickly, at longest three weeks after the infection."

"The complete result of all the here-cited infection experiments with dusty smut, millet, and corn smut affords, in the first place, indisputable proof that the germs of smut fungi which live saprophytically outside of the host plants can produce smut diseases."

"When the smut was nourished saprophytically longer than a year in continual reproduction outside of the host plant, then only did the outgrowth of the conidia into germ tubes cease. Along with this the power of infection was extinguished, *i. e.*, with the disappearance of a comprehensible morphological character, for the germs can only penetrate into the host plants by means of their germ tubes."

"The earlier view that only the young seedlings of the host plants are receptive to the fungus germ has not been sustained. On the contrary, the fungous germs can penetrate into all sufficiently young parts of the host plant."

Mycelium.—The fungus vegetates in the interior of the plant by what is termed the mycelium; a single thread being known as a hypha. In its early stages these fine threads penetrate chiefly between the cells of its host, sending short branches into the cells; these are known as haustoria. These are frequently branched, and may extend as far as the nucleus and

*Untersuchungen aus dem Gesammtgebiete der Mykologie. Heft XI. Smith. Jour. of Myc. No. 4. 6: 162. 1890.

beyond. Seymour* observes that the thicker the cell-walls which the mycelium penetrates, the more abundant are the haustoria. In later stages of the fungus the mycelium extends through and into the cells of its host, becoming densely packed, but not much beyond the point of infection. The mycelium has a peculiar glistening opalescent appearance. In course of time spores are formed from the branching mycelium by abstriction; in this way a chain of spores is formed. In appearance and color these parts do not differ essentially from the mycelium. The protoplasm is highly granular, the cell-walls become gelatinous; these walls later are absorbed, so that little else than a mass of black spores remain. As a result of the infection, the host develops an increasing number of thin-walled parenchyma cells. This is due to the action of the fungus.

Hosts.—Corn smut occurs on but two host plants so far as known. Corn is, of course, the common host plant, but Trelease has also collected the fungus on Teosinte (*Euchlaena Mexicana*), and it may be expected on related genera.

Distribution and damage.—The fungus is found wherever corn is grown. Botanical writers refer to it in Iowa, Wisconsin, the Carolinas, New Jersey, Indiana, Kansas and Texas.† I have examined specimens from Illinois, New York and Massachusetts. European mycologists report it from Italy, Ger-

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*Smut of Indian corn (*Ustilago Zea Mays*). Rept. U. S. Dept. of Agrl. 1887: 380-382.

†Tuckerman and Frost. Cat. Pl. Amherst Coll. 83.
Day. Cat. of Nat. and Native Plants of Buffalo. 143.
Ellis in Briton. Pl. of New Jersey. 506.
Trelease. Parasitic Fung of Wis. 34.
Schwienitz. Syn. Fungi. Car. 71.
Bessey. Bull. Bot. Dept. Iowa Agrl. College. 1884: 127.
Ravenel. Fung. Car. Ex. IV. 100.
Kellerman. Bull. Kan. Agrl. Coll. Exp. Sta. 23.
Bull. Neb. Agrl. Coll. Exp. Sta. 11: 67.
Norton. Trans. Acad. Sci. St. Louis. 7: 234.
H. S. Jennings. Bull. Texas Agrl. Coll. Exp. Sta 9: 29.
Hitchcock and Norton. Bull. Kan. Agrl. Exp. Sta. 62.
Kellerman & Werner. Cat. of Ohio Plants. 347.
Seymour. Rep. U. S. Dept. of Agrl. 1887: 380.
Peck. Rep. State Mus. Nat. Hist. 34: 26.
Webber. Cat. of Flora of Neb. 73.
Bessey. Bull. Neb. Exp. Sta. 11: 21.
F. Lamson-Scribner. U. S. Dept. of Agrl. Rep. 1887: 385.

many, France, England, Astria, Hungary, Belgium and Chili.*

Damage Done.—In warmer countries it is said to be much more severe than in colder countries. It appears that climate greatly influences the amount of smut present. I have† reported on the abundance of this disease in Philippine island corn grown on the college grounds. It occurred on every plant, not only affecting ears, but a large number of nodes had smut boils. The same thing was again observed in 1897 on some corn from South America and Mexico, cultivated on the college grounds.

Henry states that in the vicinity of Madison, Wis., in 1881, there was a loss of 5 to 25 per cent. This could not have been general but was most probably an unusual condition, occurring only in some fields. In 1882 personal observations showed very little smut in many parts of Wisconsin. The loss is often 25 per cent in sweet corns grown in gardens, and in fields where rotation has not been practiced.

Halsted‡ states that in 1886, the college corn field had sixty-two hundredths of 1 per cent. Bessey§ states that one year in one field 66 per cent of loss occurred. In this case the field had been in corn for several years. He further observes that 15 per cent is not uncommon. Brewer‖ observes that in 1879 there were cases in which there was a loss of 16⅔ per cent, but in most cases there was less than 1 per cent.

Maize smut not injurious to cattle.—It has been held by many that corn smut is injurious to cattle. This has been a common belief in some quarters. In some kinds of smut a small amount of ergotine is found. Professor Power of the Welcome Research Laboratory, England, found this true for the smut

*Chili. Saccardo. Syll. Fung. 7: 472.
Fischer De Waldheim. Ustilagineæ. 217.
Germany. De Bary. Die Brandpilze. 4.
Sorauer. Planzenkrankheiten. 201.
Frank. Die Krankheiten der Pflanzen. 110 (Ed. 2.)
Winter. Die Pilze. 97.
Tubeuf. Pflanzenkrankheiten. 291.
Austria. Thumen. Bekampfung der Pilzkrankheiten. 29.
Italy Comes, D. O. Crittogamia agraria. 75.
Penzig. Fungi Agrumicoli.
France. Jean Loverdo. Les Maladies cryptogamiques des cereales. 62.
Tulasne. Mem. Les Ustilagineæ 84.
England. Smith. Diseases of Field and Garden Crops. 254.

†Pammel. Fungus diseases of Iowa forage plants. 4

‡Bull. Dept. of Botany Iowa Agrl. College. 1886: 16.

§Bull. Dept. of Bot. Iowa Agrl. Coll. 1884; 127. Also Bull. Neb. Agrl. Exp. Sta. 11: 25.

‖Cereal Production of the U. S. Tenth Census Rep. 3: 107.

on *Setaria glauca*, and there are many persons who think that this smut is injurious to cattle that feed in corn fields where there is a great deal of this fungus.

Kedsie reports the following composition: Moisture, 8.30 per cent; albuminoids, 13 06 per cent; carbohydrates, 25.60 per cent; cellulose, 24.69 per cent; sugar, 4 per cent; fat, 1.35 per cent; ash, much sand, 25.5 per cent. Professor Kedsie was unable to find any poisonous alkaloids. In 1868, the United States department of agriculture employed Professor Gamgee* to ascertain the cause of the cornstalk disease.

Prof. W. A. Henry,† in a recent work says, speaking of work done by the Bureau of Animal Industry, Clinton D. Smith and Gamgee: "In experiments by the Bureau of Animal Industry, U. S. Department of Agriculture, Washington, corn smut was fed to heifers without ill effects. With all the trials but one ending without disaster, it seems reasonable to conclude that corn smut is at least not a virulent poison, if, indeed, it is one in any sense of the word. It is probable that in the Wisconsin cases, where one cow died and the other was indisposed, the animals suffered because of eating too much highly nitrogenous material rather than anything poisonous. Worse results might have followed the feeding of the same volume of corn meal or cotton seed meal. It would seem that there is little or no danger from corn smut unless cattle consume a large quantity. This is possible where they are allowed to roam through stock fields and gather what they will. There may be cases where animals seek out the smut and eat inordinately of it."

Recently Smith‡ of the Michigan Agricultural College gave the results of some experiments with corn smut. Varying amounts of smut were fed to three grade Shorthorn cows and one grade Jersey. Two of the cows were started with two ounces a day and increased to eleven pounds. Two others were started with two ounces and increased to a pound. The test lasted forty-nine days. They appeared to relish the smut. It produced no signs of abortion in pregnant cows, and the milk yield was normal. Smith concludes that the smut in corn fields is not likely to prove injurious.

*Report U. S. Dept. Agr. 1869: 73.

†Feeds and Feeding. A hand book for student and stockman. 176. 1898. See also Rep. Board of Regents, University of Wis. 1881.

‡Bull. Mich. Agrl. Exp. Sta. 137.

Beal* states that under certain conditions smut is likely be injurious to cattle. The experiments made by Moore† al indicate, like those of Smith, that smut is not injurious.

Beginning on the morning of January 17, 1894, and conti ing until noon of February 2 (sixteen and one-half days), t heifers were fed morning and evening with from two to thr quarts of a mixture of equal parts by weight of cut hay and mixture of corn meal, middlings and wheat bran, and sixte quarts of smut. No injurious affects were observed by Moo

It seems reasonable to conclude from these experiments th under proper conditions corn smut is not injurious. In o experience no cases have ever been reported to us where catt were supposed to have died from eating corn smut.

Prevention.—In previous paragraphs it has been stated th smut does not necessarilly enter the corn plant when the latt germinates but at a later period. From this it follows that will be useless to treat the seed. Experiments made at the Agr cultural college indicate, that no well-known fungicide or t hot water treatment is effective. The treated kernels in so cases contained as much smut as those not treated. As ind cated in a previous paragraph, Bessey found a considerab increase in smut where corn was planted in the same fiel several years in succession and one of us has also observed th same condition. It has also been shown that when a variet is not acclimated it is much more subject to smut. This fa has again been noticed in a striking manner, in some Sout American and Mexican corn grown on the college grounds where there had been no corn for years and no corn fields nea it this year, nor for some years. These particular varieti produce so much foliage and the vegetative organs are s vigorous that they are unable to properly resist the attacks o the fungus.

It has also been recommended that the smut boils should b carefully collected at husking time and burned. It would no be a troublesome operation to throw all smutted corn in a separate small box. This would remove the smut from the kernels, but it would be impossible to collect and destroy the smut boils on cornstalks where it is more abundant than in the ears and in smut occurring on leaves. Financially we believe that this operation would not pay. The best and most feasible

*Rep. State Board of Agrl. Mich. 1880: 288.

†Corn stalk disease. Bull. Bureau of Animal Industry. U. S. Dept. of Agrl. 10: 47. 1895.

methods would be to plant corn which is thoroughly acclimated and such varieties as are least subject to smut. Crop rotation is to be strongly urged. Corn should never follow corn. A year rotation will destroy a large number of the smut spores.

HEAD SMUT OF SORGHUM (USTILAGO REILIANA, KUEHN).

In 1875, Kuehn* described a fungus occurring upon sorghum, the *Ustilago reiliana.* Since then this fungus has been found widely distributed on sorghum in Africa, India, China, Egypt, Italy, Hungary, and Germany and in the United States it has been reported from New Jersey, Kansas, Nebraska, Iowa and Wisconsin. A related smut, *U. sorghi* Link. has also been found widely scattered in this country, on sorghum.

Ustilago reiliana attacks the upper part of the plant, especially the ear and staminate flowers, almost destroying it. In but few cases does grain mature. Hitchcock and Norton† state that "The smutted stalks are usually not over half as high as the unsmutted, and in weight are very deficient. Eleven stalks were weighed and averaged 539 grams each, while plants affected with *Ustilago maydis* from the same field averaged about 1,300 grams and healthy plants averaged 1,500 grams or more. So if this smut should ever become abundant in this country, it may seriously change the corn crop as it has the sorghum industry in other parts of the United States.

In 1876 an Italian botanist, Passerini,‡ found this fungus upon corn, but until 1895 it had never been reported on sorghum. Mr. J. B. S. Norton called attention to its occurrence in Kansas. This disease is not uncommon in Kansas and across the line near Superior, Neb. So far this fungus has not been

*Rabenhorst's Fungi Europ. 1999. Kuehn. Die Brandformen der Sorghum Arten. Mitth. d. Ver. f. Erdkunde zu Halle. 1877: 81, Saccardo. Syll. Fung. 7: 456.

Kellerman and Swingle. Notes on sorghum smuts. Bull. Kansas Agrl. Exp. Sta. 23: Sorghum smuts, Proc. Kan. Academy Sciences. 1890: 158.

Trelease. Preliminary List of Parasitic Fungi of Wis. 34.

Webber, H. J. Rusts and Smuts of Nebraska. Bull. Nebr. Agrl. Exp. Sta. 11: 69. Cat. Fl. of Neb. 74. Rep. Nebr. State Board of Argl. 1889:

Saccardo. Syll. Fung, 7: 471.

†Hitchcock and Norton. Bull. Kansas Agrl. Exp. Station. 62: 198.

Norton, J. B. S. A study of the Kansas Ustilagineæ. Trans. Acad. of Sci. St. Louis 7: 231.

Frank. Krankheiten der Pflanzen. 111 (2 ed.)

Tubeuf. Pflanzenkrankheiten. 303.

Sorauer. Pflanzenkrankheiten. 209.

Comes. Crittogamia Agraria. 75, 537.

Saccardo. Syll. Fung. 7: 471.

‡Passerini. La Nebba dei cereali. 1876.

Bot. Gazette. 20: 163. 1895.

Fig. 112. Head smut of sorghum (*Ustilago Reiliana*) on tassel of corn. (From Kansas Agri. Exp. Sta.)

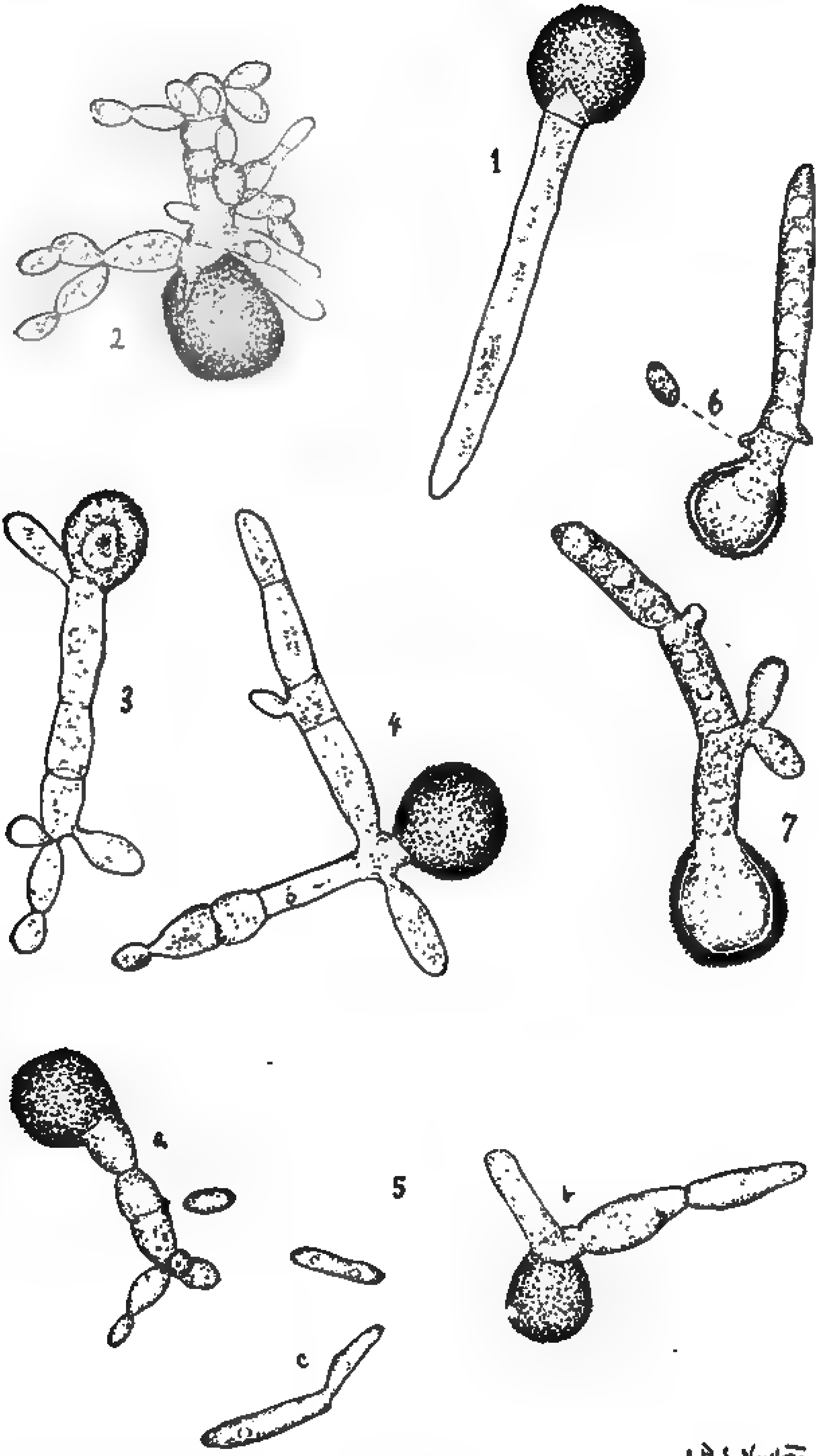

Fig. 113. Head smut of sorghum (*Ustilago Reiliana*). *1, 2, 3, 4*, germination in water after three days; *5*, after forty-eight hours in water. A, with detached conidium, showing point of attachment; C, conidia from another spore; *6, 7*, spores germinating thirty-six hours after. (Norton. Kansas Agrl. Exp. Sta.)

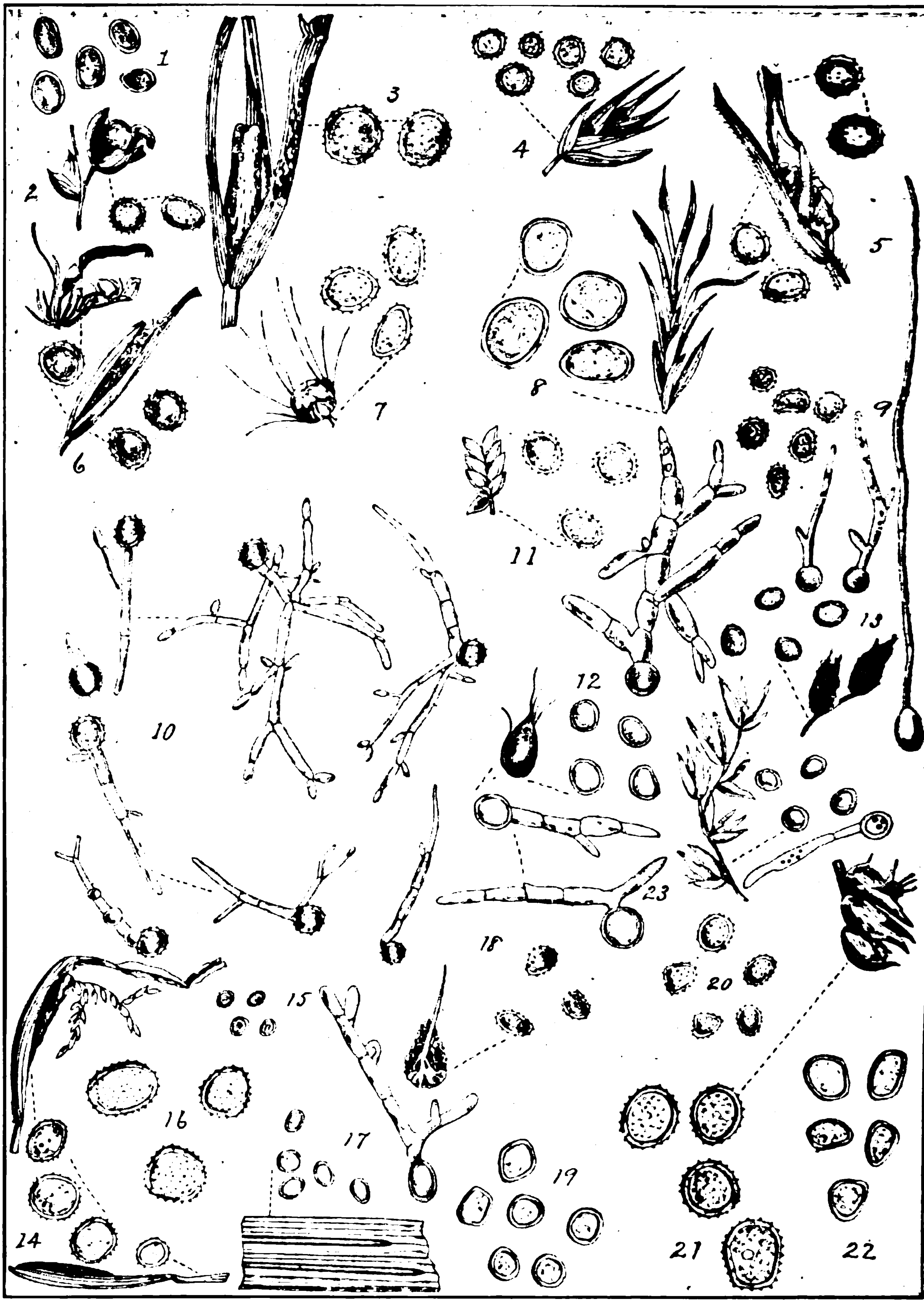

Fig. 114. Smut diseases of grasses. *1, Ustilago panici-miliacei* on *Panicum miliaceum; 2, U pustulata* on *Panicum proliferum; 3, U syntherismæ* on *Panicum proliferum; 4, U. bromivora*, var. *macrospora* on *Bromus breviaristatus; 5, U. syntherismæ* on *Panicum capillare; 6, U. syntherismæ* on *Cenchrus tribuloides; 7. U. neglecta* on *Setaria glauca; 8, U. buchloes* on *Buchloe dactyloides; 9, U avenæ*, var. *levis* on oats; *10*, germinating spores of corn smut; *11, U. spermophorus* on *Eragrostis major; 12, U. hordei* on barley; *13, U. avenæ* on oats; *14, U rabenhorstiana* on *Panicum sanguinale; 15, U. hypodytes* on *Stipa spartea; 16, U. montaniensis* on *Muhlenbergia glomerata; 17, U longissima* on *Glyceria arundinacea; 18, U. nuda* on barley; *19, U aristidæ* on *Aristida purpurea; 20, U. tritici* on wheat; *21, U. sorghi* on sorghum; *U. perennans* on *Arrhenatherum avenaceum; 22. U. lorentziana* on *Hordeum jubatum; 23, U segetum.* (Pammel and King.)

reported in this state on corn, and the following account has been taken from Hitchcock and Norton, who have especially studied the disease. "It appears in tassels and ears as a rather hard, compact mass of smut, of a rough granular appearance. It does not have the large soft swellings that *Ustilago maydis* has bu at first the ovate pointed mass of smut is inclosed in a white membrane as is the case with *Ustlago maydis*, but this soon disappears. On older smutted places, the large fibro-vascular bundles of the corn gives the smut mass a coarse, stringy appearance. The smut is usually seen best in the tassel or upper part of the plant, the whole upper portion often being converted into a smutty mass just above the ear. When it attacks the ears, the husk usually conceals it until late in the season. The smut usually attacks all the ears, rudimentary ears or shoots on the stalk, converting them into masses of smut but not enlarging them. Often the tassel may not be smutted but usually is. Sometimes when the smut is not very bad on the stalk the flowers are curiously deformed. The ears are almost always attacked and often a cluster of ears is borne where there is normally but one. Often instead of producing flowers, and not actually smutted, the floral organs grow into long projections"

Microscopic characters.—The characteristic spores are larger than corn smut, being from 7^u to 15^u in diameter and nearly smooth. The outer wall of the spores is provided with very fine spines. Spores germinate readily in water, by producing a rather long, divided and frequently branched promycelium. Secondary sporidia are also produced. Brefeld observed that these spores retained their vitality for eight years at least when placed in nutrient solution they germinated.

In addition to its occurrence on maize, sorghum is a frequent host. It was found on sorghum in Kansas in 1890 by Kellerman.* It has also been found in this state, in Jones county, by Mr. Reed. It presents the same general characters on sorghum as on maize.

KERNEL SMUT OF CORN.

This smut (*Ustilago Fischeri*, Pass.), was described by the same Italian botanist, Passerini.† This affects the kernels,

*Proc. Kas. Acad. Sci. 1890: 153. Bull. Kas. Agrl. Exp. Sta. 23.

†Di una nuova specie di carbone nel granturco. Estratto Boll. del comizio agra Parma. Novembre, 1877. 4. Just. Bot. Jahresb. 1877: 123.

although sometimes the adjacent bracts also. A large number of kernels may be affected. On breaking the kernels open, a powdery mass mixed with starch may be seen. The starch grains are corroded, showing that in the action of the fungus a ferment dissolves the starch. The spores are spiny and measure from 4 to 6$^{\mu}$ in diameter. Very little is known of the fungus. It was distributed by Von Thumen* and Rabenhorst † It is described by Loverdo,‡ Tubeuf§ and other mycologists. It is not referred to by Farlow and Seymour in their valuable host index. So far as known it does not occur in this state, but the writer has received it from Jamaica.

Fig. 115. Kernel smut of maize (*Ustilago Fischeri*) on maize, spores to right, below, a sectional view of an affected kernel. (Pammel and King)

This fungus is probably a tropical or subtropical species, and may occur in southern United States. It certainly occurs in the West Indies. The writer some years ago found it among some ears of corn sent to him by Wm. Fawcett, the director of the botanical garden at Jamaica.

KERNEL SMUT OF SORGHUM.

This parasitic fungus (*Ustilago Sorghi* (Link) Winter), is quite widely distributed in the United States, though not as common as many other economic smuts. Link,‖ in 1825, described it under the name of *Sporosporium sorghi*. Tulanse¶ named it *Tilletia sorghi-vulgaris*. Kuehn** gave it the name of *Ustilago tulasnei* in 1874. In 1897 Mr. G. P. Clinton†† studied the fungus and applied the name of *Cintractia Sorghi-vulgaris* (Tul.), Clinton. This was done in order to avoid confusion with the doubtful *Cintractia* (?) *Sorghi* (Sorok.) De Toni.‡‡ The first reference to the occurrence of this fungus in this country was by Trelease,‡‡ who found it on imported seed of sorghum grown in Wisconsin, further stating that Farlow had received it from the Depart-

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*Mycotheca universalis. 1624.

†Rabenhorst. Fungi Europ. 2500.

‡Les maladies Crypt. 80

§Tubeuf. Pflanzenkrankheiten. 296.

‖Linn. Sp. Pl. 62. 96. 1825. (Ed. Willd.)

¶Ann. d. Sc. Nat. III. 7: 116. *pl. 5 f 17-22.* 1847.

**Sitzb. natur. Gesellsch. Halle, 1874: Bot. Zeit. 32: 122. 1874.

The fungus has been distributed by Rabenhorst, Fung. Europ. No. 1997. Thumen, Herb. Myc. Oec. No. *63*. Briozi and Cavara, Fungi Parasit. No. *28*. Ellis, North Am. Fung. No. *1496*. Roumeguere, Fung. Selecti Exiss. No. *5128*.

††Broom corn smut. Bull. Univ. Ill. Agri. Exp. Sta. 47. This paper contains an excellent bibliography.

Syll. Fung. 7; 481.

‡‡Parasitic Fungi of Wis. 34. 1884.

ment of Agriculture, Washington. These specimens, it appears, came from New Jersey. It was also reported from New York to Trelease by Sturtevant. Webber* reported it on Millo maize in Nebraska in 1889. It was reported as common in Kansas by Kellerman.† Hitchcock has kindly furnished me with specimens from Kansas, and in Clinton's paper on Broom Corn Smut the statement is made that it occurs on Early Amber, Rangoon, Red Liberian and many others; also on broom corn and Kafir corn. In 1899 it was found on Kafir corn at Ames by Mr. Evers. In Illinois it was first collected by Waite‡ in 1887, at Urbana. Further localities are reported by Clinton.§

Characters of the fungus.—The diseased plants attain their normal height. The panicle is elongated and all of the seeds are destroyed. In the case of broom corn as described by Clinton it is as follows: "An examination of the brush of an infected plant, unfortunately, shows that it is of a very inferior grade, usually almost worthless. Here, then, is a much more important loss, for the brush is the part for which broom corn is raised. Good broom corn has the rays of about uniform thickness and length, and all springing from a series of very contracted nodes so as to give them about the same point of origin. In the case of infected plants these internodes are usually elongated, and the rays are of unequal lengths, so that there are a series of irregular rays arranged on an elongated and thickened central axis—qualities very undesirable."

The covering of the grains is pale. At maturity the grains are grayish in color. Finally the membrane becomes broken, permitting the spores to escape. The whole interior of the ovary is converted into a mass of spores, the anthers being also affected. The spores are spherical, or somewhat angular, rarely elliptical, 5–9.5 x 4–5.5^{u}. The spores germinate readily when placed in water. Clinton states that spores 1 year old germinate. Some writers state that spores 6.5 years old germinate.

Infection takes place by the penetration of sporidia as well as the "infection threads." According to Clinton, entrance to the plant takes place at the growing point. "Thus the germinating seed in its early stages is the only place where the broom-corn is liable to become successfully infected. As a

*Ann. Rep. Neb. State Board of Agrl. 1889. 214. 1890.

†Bull. Kans. Agrl. Exp. Sta. 23.

‡Bull. Univ. Ill. Agrl Exp. Sta. 47: 376.

§l. c.

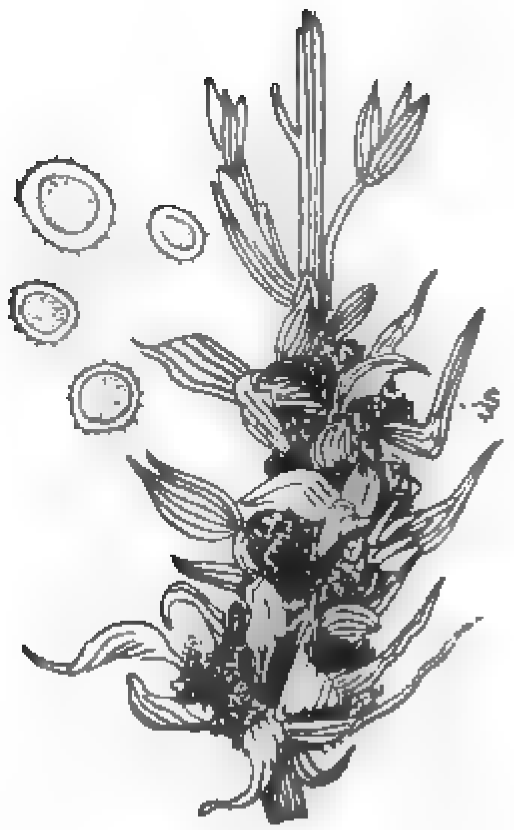

Fig 115A. Kernel smut of sorghum (*Ustilago sorghi*) The affected inflorescence to the right and spores to the left.

germinating plant becomes older and its tissues harder of penetration by the threads, infection becomes less possible until, at the time when the plant breaks through the ground and its first leaves show, it is practically exempt from successful infection." Short treatment of the seed with warm water has no injurious effect. Experiments made for three years by Clinton showed favorable results by treating with hot water. The spores were killed at 135° F.

Ustilago cruenta. — Another smut affecting this host has been described by Kuhn*—the *Ustilago cruenta*. This species produces brownish-red spherical or elongated enlargements which contain the smut spores affecting any part of the panicle. The somewhat variable spores are 5–12$^{\mu}$ long x 5–9$^{\mu}$ wide, smooth yellowish or brownish, germinate readily in water, and in nutrient solutions produce abundant secondary conidia. Kuehn† surmises that it is the cause of a destructive disease Durra of millet in Africa.

LOOSE SMUT OF WHEAT.

For a long time all of the loose smuts—oats, wheat and barley (*Ustilago tritici* (Persoon) Jensen)—were considered by botanists to be one species, to which the name *Ustilago segetum* (Bull) Dittm.‡ was applied. This smut was known to writers as early as 1552, when Tragus§ applied the name *Ustilago* An early writer, Bauhin, 1595, described it as *Ustilago secalina.*‖ None of the early writers, however, recognized it as a fungus. Persoon, an early mycologist, gave it the name of *Uredo tritici,*¶ considering it a variety of *Uredo segetum*. Other names were subsequently applied, and in 1888, Jensen** reported that wheat

*Hamburger Garten u. Blumen Zeitig. 28: 177.

†Tubeuf. Pflanzenkrankheiten. 305.

‡Sturm Deutsch. Fl. 3: 67 pl. 33.

§Die Stirpium Nomencl. Prop. Lib. 3: 666.

‖Phytopinax. 52.

¶Syn. Meth. Fung. 224.

**The Prop. and Prev. of Smut in Oats and Barley. Jour. Roy. Agrl. Soc. 24: 8.

smut would infect only wheat plants. Oat smut would not produce wheat smut, nor barley smut produce smut in wheat. Kellerman and Swingle* give a full bibliography. It is described under *U. segetum* in the works cited below:

Distribution and damage.—This disease occurs wherever wheat grows. We have observed it abundant in many portions of Iowa where wheat is grown; also in Minnesota and Wisconsin. According to Dr. Erwin F. Smith, it is common in Michigan. Kellerman and Swingle also report it as common in Michigan. In a collection of smuts prepared for the World's Fair this was sent to me from many states. It is reported as common in Nebraska (Bessey), Indiana (Arthur), North Dakota (Bolley) and New York (Beach). It is also common in Germany (Sorauer, Frank, Tubeuf, etc), England (Plowright and Marshall Ward). These references suffice to show that this fungus is of wide distribution. The damage caused by this smut is often very considerable. It is the one most familiar to the Iowa farmer. Perhaps the loss to Iowa farmers is not far from .5 per cent. Dr. Erwin F. Smith reports that he observed in a patch of five acres in Michigan a loss of 50 per cent in 1870. Much of this loss can, no doubt, be prevented by judicious culture.

General characters.—The affected plants are lighter green in color. The smut converts the chaff, and frequently all adhering parts except the central stalk, to a powdery mass. The smut is not covered with a membrane. As Professors Kellerman and Swingle say, "The spores are completely free, and in this species is perhaps the dustiest of all loose smuts." The wind removes nearly all of the smut excepting a small portion adhering to the central stalk. Unlike bunt, not all the stalks of a stool are affected. Professor Bessey, some years ago, noted this fact of wheat grown at Ames.

In 1892 the writer made some observations on two varieties of wheat grown on the college farm in which the same results were obtained.

This fact clearly indicates that the manner of infection is very different than in bunt or loose smut of oats.

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*Rep. Kansas Agrl. Exp. Sta. 1889: 261.
Tubeuf. Pflanzenkrankheiten. 303; under *U. tritici.*
†Saccardo. Syll. Fung. 7: 461.
Sorauer. Pflanzenkrankheiten. 198.
Frank. Krankheiten. d. Pflanzen. 110. (Ed. 2.)
Marshall Ward. Diseases of Pl. 86. Plowright. British Ured. and Ustilag. 273.

Microscopic characters.—The powdery mass is made up of large number of very minute brown-colored spores with a olivaceous tinge, especially when in masses. The spores ar somewhat variable in size, usually nearly round, or angula or elliptical.

Germination of the spores.—It is not difficult to obtain germi nating spores in sterilized water, but the process is slowe than in oats smut. In germination a tube (promycelium) pushed through the light colored outer wall of the spore (epi pore). Sporidia are not produced. In nutrient solution ge mination begins in fifteen hours, starting in the same way, b more vigorous. Sometimes these become very long. Th segments frequently break up.

OATS SMUT.

Oat smut (*Ustilago avenae* (Pers.) Jensen), has long bee known to mycologists. Until the elaborate investigations Jensen* it was regarded as identical with that occurring wheat and known as *Ustilago segetum*. It was called *Ure avenae* by Persoon.† The literature is cited quite fully by Ke lerman and Swingle.‡

COMMON LOOSE SMUT OF OATS.

The oats (*Ustilago avenae* (Pers.) Jensen), is affected by tw smuts; one is the common loose smut of oats (*Ustilago avena* a disease long and well known to agriculturists. This sm converts the flowers especially, the grain and adhering par to a black, powdery substance. It may affect all of the flowe or only a part.

In most cases it completely destroys the tissues of the spik lets, leaving a black mass of spores with threads and tissu of the plant. The smut, during its early stages, is covere with a membrane. The spores are free and form a dusty ma of olive or dusky brown color; they are oval, sub-globose, elli tical or somewhat angular, irregular or deformed, and light on one side; contents usually clear or slightly granular. Th outer wall or exposure is minutely warty.

Germination.—The spores germinate readily in water; the are said to retain their vitality for a number of years. We hav

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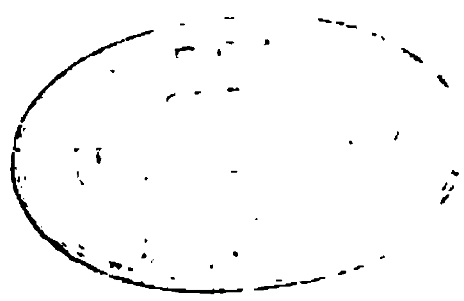
*Le Charbon des Cereales. 4: 1889.

†Syn. Meth. Fung. 224. 1801.

‡Rep. Kans. Agrl. Exp. Sta. 1889: 215. Bull. Kans. Exp. Sta. 8: 15. See also Bolley. Bull. North Dakota Agrl. Exp. Sta. 1: Arthur. Bull. Indiana Agrl. Exp. Sta. 35: Syll. Fung. 7: 461.



had no difficulty in getting fresh spores to germinate abundantly in twenty-four hours. The promycelium is slender and bears narrow, elliptical bodies called sporidia, which later cause the infection of the plant. The spores also germinate readily in normal nutrient solütion, frequently budding. Brefeld observed that the sporidia, when transferred to a nutrient solution, continued to form sporidia. He obtained these yeast-like spores for many generations.

Manner of infection.—Infection in this smut is probably by way of the seed. Wolff, in his classic experiments, found that smuts entered through the first formed leaves. Brefeld's classic experiments also indicate that infection takes place during the early stages of the germination of oats.

Jensen thinks that smut does not enter with barnyard manure, and he supports it by some evidence:

	1885.	1886.
Barnyard manure plot........	42 smutted heads........	1.2 per cent smutted.
Artificial manure plot........	35 smutted heads........	1.0 per cent smutted

He furthermore suggests that infection is brought about by spores contained in the husks which lodged there while the oats were in flower, but this is contrary to the usual experience. Kellerman and Swingle state: "In an experiment of ours in June, 1888, a square rod of oats just in blossom were dusted with smut spores in considerable quantity on the 20th, 22d, 25th and 27th of the month. When ripe it was harvested and kept separate In the spring of 1889 it was planted, together with other plots, with seed from other parts of the same field. One of the artificially infected plots (23) was 6.8 per cent smutted, and the other was 5.36 per cent, while the untreated plot had 6.4 per cent of smut, midway between the two artificially smutted ones."

Damage and distribution.—The damage done by this smut is very large. Arthur gives the following percentages in different varieties grown at Geneva, N. Y.: "J. C. Arthur, in 1884, gave the results of counts of oats grown on the farm of the New York Agricultural Experiment Station at Geneva, N. Y., and found American Triumph, of 1,237 heads counted, had 10 per cent smutted."

Arthur* estimates the loss for Indiana at $797,526. Jones† examined 35,177 heads for oats smut; the average smut in 1892

*Loose Smut of Oats. Bull. Purdue Univ. Agrl. Exp. Sta. 35: 83.

†Annual Report of Vermont Agrl. Exp. Sta. 6: 73-83.

was 1.6 per cent. On this basis Swingle* estimates the loss in that state to be $26,454. From these figures Swingle† thinks 8 per cent a low average. This would entail a loss of $18,000,000 annually. Averaging 18,504,140 for the years 1890–1893.

On our own grounds we have found oats smut less common than the figure given by Swingle.‡ Harwood and Holden§ estimated the loss in Michigan in 1892 at $1,000,000.

Is it any wonder that smut should be so abundant since a single head may contain millions of spores?

Dr. Cobb says: "A single head of smutted oats may easily contain 500,000,000 spores; that is to say, a number of spores so great that if they were distributed evenly over an acre of land there would be over 1,000 spores on every square foot. In as much as these spores are instrumental in spreading the smut disease, we shall no longer wonder at finding the disease so common."

KERNEL SMUT OF OATS.

In addition to the above smut (*Ustilago avenæ* (Pers.) var. *levis*, Kellerman and Swingle) another form has been observed by Kellerman and Swingle,‖ which destroys only the grain and does not affect the glumes. On cutting open such a diseased husk the whole interior of the grain will be found converted into a powdery mass consisting of spores. This species was collected by Farlow and distributed by Ellis¶ in his North American fungi. The spores of this smut are dark brownish, oval, elliptical or subglobular, 6–12 x 55–8^{u}, usually 6–9 x 6–7^{u}. The exospore is nearly smooth. The spores germinate readily in nutrient solutions, producing short promycelia and narrow germ tubes. The species is probably quite widely distributed though not nearly so common as *Ustilago avenæ*.

BARLEY SMUT.

Barley is affected by two well-known smuts in Iowa. The covered barley smut (*Ustilago hordei* (Persoon) Kellerman and Swingle) and the naked barley smut (*Ustilago nuda* (Jensen) Kellerman and Swingle). Formerly both of these smuts were

*The Grain Smuts. Their Causes and Prevention. Year book U. S. Dept. Agr. 1894: 413

†I. c. 413.

‡Bull. Mich. Agrl. Exp. Sta. 87: 189.

§Rep. Kansas Agrl. Exp. Sta. 6: 259. 1890.

‖Ellis. North Am. Fung. 1091.

¶Swingle. Year Book U. S. Dept. Agr. 1894: 412. Farmers' Bulletin U. S. Dept. Agr. 75.

supposed to be identical with the smut occurring on wheat and oats.

The covered barley smut is said to be less abundant in Denmark than the naked barley smut, but it is quite widely distributed in Europe. It is also widely distributed in the United States: New Hampshire (Farlow), Maine (Harvey), Kansas (Kellerman and Swingle), Michigan (Beal), Indiana (Bolley), New York (Peck), and Iowa (Pammel, Stewart and Weaver). It is more common in Iowa than naked smut. This smut was first named by Persoon* and the correct combination was made by Kellerman and Swingle† who cite the very full literature. This smut differs from all other loose smuts, in that the panicle is not converted into a loose powdery mass, but is more or less covered by a membrane, which breaks and allows the spores to be scattered through the broken membranes.

Fig. 116. Covered Barley Smut (*Ustilago hordei*). (King.)

The spores of *U. hordei* are dark colored, spherical, slightly irregular, 5–8 x 5–7^{u}, usually 6–8 x 7^{u}, somewhat larger than *U. nuda.* The exospore is smooth. Germination proceeds readily in water with abundant sporidia from which secondary sporidia occur.

In naked barley smut the parts of the flowering panicle attacked are converted into a loose powdery mass, thus allowing the spores to be blown away very readily. The membrane covering the smut is very thin, dark, dull gray in color and easily broken. It consists of the modified epidermal cells of its host; the whole of the inflorescence being converted into a blackish powder. Kellerman and Swingle say: "The reason, notwithstanding the presence of fibers and a thin enveloping membrane, this species spreads its spores very readily and seems wholly different from typical

*Syn. Meth. Fung. 224.

†Rep. Kansas Agrl. Coll. 1889: 268.

Ustilago hordei, is found in the fact that the spores are free, and do not adhere to each other or to the shreds of the host tissue. The infecting threads, unlike those of the *Ustilago hordei*, grow to their normal height, and do not tend to remain enclosed by the uppermost sheath of the barley plant." In *Ustilago hordei* the thin membrane encloses the smutted kernel until harvest time. The spores are free, forming a dark mass of olive color, sometimes elliptical or sub-globose, usually the one side lighter than the rest, as in the other loose smut. The spore wall consists of two parts, the exospore and endospore. The exospore of *U. nuda* is slightly roughened. The spores germinate in sterilized water and nutrient sugar solution under favorable conditions of temperature usually in twenty-four hours or less. The promycelium or germ tube comes out of a large germ pore. It is curved and slender. According to Kellerman and Swingle it attains its full length in thirty hours. Sporidia are not produced, according to Kellerman and Swingle. This smut occurs in Kansas, Iowa, Wisconsin, New York, Michigan, Minnesota and Europe.

Manner of infection.—Little is known of the manner of infection; the seeds of the smut apparently propagate the smut so that infection is carried with seed barley.

WILD BARLEY SMUT.

This smut (*Ustilago lorentziana*), converts the ovary, palet and flowering glume of *Hordeum jubatum* into a black, powdery mass, as in *Ustilago nuda*. The spherical spores are minutely roughened. This species does good service in the northwest in destroying much of this detestable weed.

OTHER SMUTS OF THE GENUS USTILAGO.

Pigeon-grass smut (*Ustilago neglecta*, Niessl.) The most common of our smuts is that occurring on Setaria or pigeon-grass (*S. glauca.*) *Ustilago neglecta* was first described by Niessl* and has been reported by numerous American and European† mycologists. In Europe‡ it is said to effect *S. glauca*, *S. verticillata* and *S. viridis*. I find, however, no record of its occurrence on any other host but *S. glauca* in this country.§ On this host‖ it is extremely common, not only in Iowa, but throughout

*Rabenhorst. Fung. Europ. *1200*.
†Winter die Pilze. 1: 97 as U. *Panicici-glauci*.
‡Tubeuf. Pflanzenkrankheiten. 306.
§Saccardo, Syll. Fung. 7: 472.
‖Farlow and Seymour. Host Index.

the neighboring states. This fungus converts the ovaries into a powdery mass, consisting of spherical to ovoid spiny spores, 9–16 x 7–11µ.

Covered smut of switch grass (*Ustilago syntherismæ.* (Schw.) Ell. & Ev.) This is widely distributed in the United States and is indeed common wherever *Panicum capillare*, *P. proliferum* *Cenchrus tribuloides* occur. Norton,* who has studied the germination of Kansas smuts, places under this species provisionally several of the smuts which are much alike. It certainly appears that the forms on the above weeds germinate in much the same way, but rather difficult in water. On *Panicum proliferum* and *Cenchrus tribuloides* the ovaries as well as the whole inflorescence become greatly enlarged, and for considerable time the spore mass is surrounded by a white membrane, which, on drying, breaks, allowing the spores to be liberated. The spiny spores are variable in size, 10–12µ in diameter, ovate or somewhat polyhedral 12 x 14µ, to oblong polyhedral 12–14 x 8–10µ. This smut prevents the production of seed. The plants are much dwarfed. The allied *U. rabenhorstiana*, Kuehn†, also converts the whole inflorescence into a powdery mass. The affected plants are dwarfed and more branched; the minutely roughened spores are spherical to oblong elliptical 8–14 x 7–11.5µ. The promycelium is branched; conidia are absent. Another form affects the individual flower, and not the inflorescense, as in the usual form. This smut is extremely common and destroys a large number of plants every year in this state.

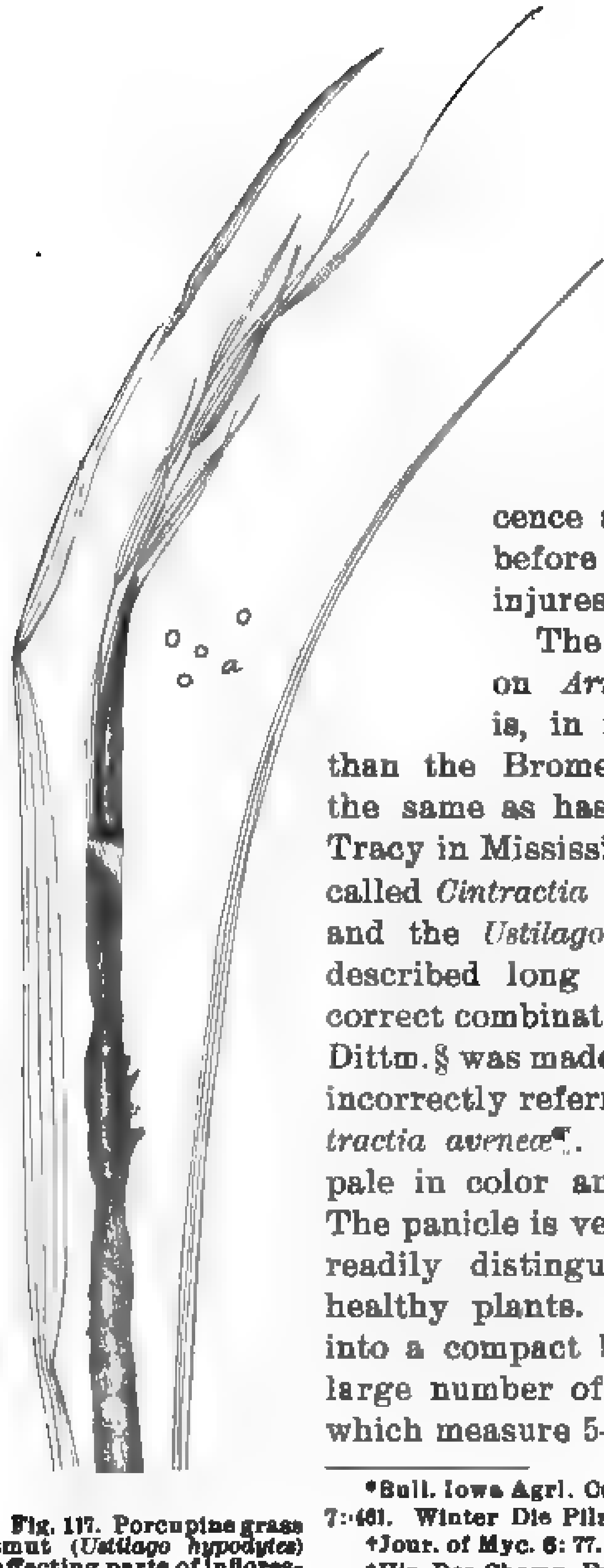
Some of our cultivated grasses are affected with other members of the genus Ustilago. In some cases they affect very valuable grasses. One of these, *Ustilago bromivora* var. *macrospora*, was found on one of our native and valuable grasses, *Bromus breviaristatus*, by Mr. F. A. Sirrine on the college farm. This, as well as the smut on tall meadow oat grass, was described by the writer‡ some years ago.

Brome grass smut affects parts of the flowers causing them to develop into a powdery mass. In tall meadow oat grass I also observed that all the stalks of a stool are affected, clearly showing that the fungus enters early in the development of the plant. The *Ustilago bromivora*, Fisch. de Wald. is apparently the variety *macrospora* of Farlow. It occurs abun-

*The Kansas Ustilagineae. Trans. Acad. of Sci. St. Louis. 7: 235.

†Hedwigia. 15: 4. 1876.
Saccardo Syll. Fung. 7: 471.

‡Jour. Myc. 7: 98.



dantly on one of the best of our native species of Bromus, the *B. breviaristatus* and it has been reported on *B. ciliatus* by Dr. Halsted.* It affects the inflorescence so as to completely destroy it. This smut will probably not occasion much loss, as it attacks the inflorescence and the grass can be cut before it appears, but it greatly injures its vitality.

The *Ustilago perennaus* iu common *Arrhenatherum avenaceum*; it is, in fact, much more common than the Brome smut and seems to be the same as has been found by Professor Tracy in Mississippi on the same host, and called *Cintractia aveneæ*, Ellis and Tracy,† and the *Ustilago segetum* of some writers described long ago by Bulliard.‡ The correct combination *Ustilago segetum* (Bull.) Dittm.§ was made much later. The writer‖ incorrectly referred the Iowa smut to *Cintractia aveneæ*¶. The affected plants are pale in color and somewhat drawn out The panicle is very light in color and is readily distinguished from surrounding healthy plants. The ovary is converted into a compact brown mass made up of a large number of small sub-globose spores which measure 5–6" in diameter.

Fig. 117. Porcupine grass smut (*Ustilago hypodytes*) affecting parts of inflorescence and culm; *a*, spores. King.

*Bull. Iowa Agrl. Coll. 1886: 59. Saccardo. Syll. Fung 7:461. Winter Die Pilze 1 77.

†Jour. of Myc. 6: 77.

‡His. Des Champ. Fr. 1: 90 *pl.* 474.

§Dittm. in Sturm Deutsch Fl. 3: 67. *pl.* 33.

‖Jour. Myc. 7:36.

¶Rostrup Ustilagineæ daniæ 139 named the fungus *U. perennans*. See Tubeuf Pflanzenkrankheiten. 299.

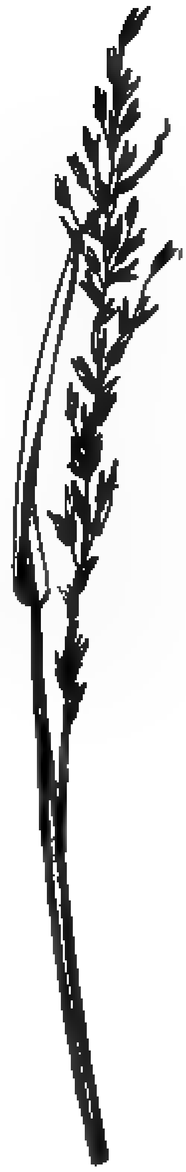


Fig. 118 Sprouting grass smut (*Ustilago panici-miliacei*) showing large swelling in upper part of plant. (King.)

Fig. 119 Tall meadow oat smut (*Ustilago perennans*). (King.)

Barnyard grass is affected with several smuts which, by some mycologists have been placed in the genus Ustilago. Burrill* described an *Ustilago sphaerogena* occurring in the ovaries of barnyard grass. The pustulate swellings of the spikelet vary greatly. The Burrill specimen is identical with *Sorosporium bullatum* Schr.† or *Tolyposporium bullatum* Schr. The spore masses are spherical or elongated, consisting of many spores. The individual spores are somewhat polygonal, with a few warty projections. This is true of the specimen collected by Seymour in Osborne, Ill., and the Arthur specimen from Ames. The writer has collected a somewhat similar fungus with larger spores which are more minutely echinulate, in

*Ellis and Everhart. N. Am. Fung. No. 1892.
Saccardo Syll. Fung. 7: 468.
Winter die Pilze. 1: 104.

†Krypt. Fl. Schles. 276. Saccardo Syll. Fung 7: 502.
Bull. Torr. Bot. Club. 22: 175.

Clinton, Iowa. A second fungus has been described by Tracy and Earle on this grass, namely, *U. crus-galli.* This fungus affects the panicles and upper nodes. The mass of spores is covered by a more or less persistent membrane. The pustules in some cases are quite large, an inch or more long. The round spores are minutely roughened and measures 8–12^u in diameter. Magnus* described a smut on barnyard grass, the *Cintractia seymouriana*, and in a later number of the same journal changes the name of the fungus to *C. crus-galli* (Tracy and Earle)†, Magnus. The spores and general character of the fungus makes it closely allied to the Burrill fungus, but the spores examined by the writer are globose or nearly so, and somewhat smaller. The *U. bullata*, Berk., produces pustulate swellings in the individual spikelets of a species of Triticum. These vary somewhat in size, but it is evidently closely allied to *U. sphaegroena.* The *Ustilago bullata* is allied to the *U. pustulata*, Tracy and Earle,‡ which occurs on *Panicum proliferum.* It infests the ovaries, forming rounded bullate swellings. Spores dark brown, oval to sub-globose, slightly echinulate, found at Ames. *U. Panici miliacei* (Pers.) Wint. is widely distributed in Europe on *Panicum miliaceum* and *P. crus-galli.* It produces large distorted swellings in the inflorescence very much like *P. syntherismæ.* The fungus on *Panicum capillare* is sometimes referred to *U. panici miliacei.*

Manna grass smut (*Ustilago longissima*), Sow., Tul.,§ is common on species of Glyceria, producing elongated gray pustules in the leaves. These pustules contain the globular, smooth spores which measure 3–6 x 3–4.5^u in diameter. The latter germinate readily in a damp atmosphere or in water. The writer obtained abundant germination by keeping the spores in a vasculum or in a closed vessel for twenty-four hours. The short promycelium is narrow and straight. It produces from its end a one-celled conidium. The writer has found this species on *Glyceria arundinacea.*

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*Ber. d. deut. Bot. Gesellsch. 14: 216.

†l. c. Heft. 9.

Syll. Fung. 7: 468. Berkley and Hooker. Antarct. Voy. 199. pl. 106. f. 12.

‡Bull. Torrey. Bot. Club. 22: 175.

Tubeuf. Pflanzenkrankheiten. 301. Winter Die Pilze. 1: 89. Saccardo Syll. Fung. 7: 54.

Uredo longissima. Sow. in Berk. Engl. Fl. 5: 375. t. 139.

§Tulasne. Mem. Sur. les Ustil. Ann. d. Sci. Nat. Bot. *III.* 7: 76.

Saccardo. Syll. Fung. 7: 451.

Plowright. Mon. Brit. Ured. and Ust. 272.

The *Ustilago sacchari*, Rabh., is a destructive smut in Italy, Java and Africa, occurring on the stems of *Erianthus* and *Saccharum*.

Porcupine grass smut (*Ustilago hypodytes*), Schlecht. Fr. This smut is very common on porcupine grass (*Stipa spartea*). Arthur* records its occurrance on *Elymus canadensis*. The writer has never met with it on any member of the genus Elymus, although it is extremely common at times on the porcupine grass. It was described by Schlechtdendahl† as *Caeoma hypodytis*. Fries‡ transferred it to the genus Ustilago. This name is adopted by Saccardo§ and also by Plowright.‖

This fungus is characterized by its occurrence in the culms beneath the leaf sheath. It is most common during the latter part of May and early in June. It frequently destroys large patches of this grass. In addition to the host mentioned above, it occurs upon quack grass, Calamagrostis, Bromus and Phragmites. Its distribution is quite common throughout Europe and northern Africa, but as stated above, it usually occurs in this state upon the Stipa.

Wild timothy (*Mulenbergia glomerata*) is affected with *Ustilago montaiensis*, Ell. & Holw.¶ This smut affects the ovaries, causing them to become greatly enlarged, very much like *Ustilago bullata*. The smutty mass is surrounded by a persistent membrane, which later cracks and breaks. The glumes and bracts are pale in color. The spores are brown and minutely roughened. This fungus appears to occur only in Montana, but ought to be looked for in this state.

The *Ustilago buchloes*, Ell. & Tracy, affects the leaves of buffalo grass, causing enlargements. The smut is covered by a delicate membrane which soon becomes ruptured, and this distributes the spores. The spores are brown and smooth. It occurs in the southwest.

Ustilago andropogonis, Kellerman and Swingle,** occurs upon tall blue stem, *Andropogon provincialis*. This smut causes the host plant to flower several weeks earlier and dwarfs the

*Iowa Ustilagineae. Bull. Iowa Agrl. Col. Dept. of Bot. 1884: 172.
†Flora Berol. 2: 129.
‡Syst. Myc. 3: 518.
§Syll. Fung. 7: 453.
‖Mono. of the British Ured. and Ustilag. 273.
¶Ellis and Everhart. N. Am. Fung. No. 2263.
**Jour. Myc. 5: 12.

affected plants. It affects the ovaries. The spores are dark brown or black, sub-globose or slightly oval.* The fungus appears to be closely allied to if not identical with *Sorosporium ellisii*, Winter,† and this specific name should therefore be used. The Cerebella is allied to the Sorosporium; one species, the *C. spartinæ*, occurs and affects the spikelets of slough grass.

The *Ustilago aristidæ*, Pk., was described by Peck.‡ It occurs upon *Artistida purpurea*. It is common in parts of Nebraska where the writer has found it covering wide areas. It has been reported by Norton from Kansas. This smut fills the ovaries, and the awns are much shorter than usual. An Ustilago also occurs on *Sporobolus*, *vaginæflorus*, the *U. vilfæ.*§ The *Ustilago spermophora*, B·rkley and Curtiss ‖ is very common at times on *Eragrostis major*. Generally only a few of the ovaries are smutted, but in some cases entire sections of the panicle were affected. The spores are sub-globose and minutely roughened. During the past season, 1899, it was extremely common here in this state.

BUNTS (TILLETIA).

Wheat is attacked by two species of bunt in this country, the *Tilletia foetens* (B. & C.) Schroeter, and *Tilletia tritici* (Bjerk) Winter. Of these the former is far more common. Both are exceedingly destructive to wheat.

Tillitia foetens (B. & C.) Schroeter. This fungus was first described by Berkeley and Curtiss;¶ earlier than this it was recognized by Wallroth.** Kuehn, in 1874, gave it the name of *T. laevis*. It usually passes under this name in European mycological works, so given by Sorauer,†† Frank‡‡ and Tubeuf.§§ This name is also used in Massee's‖‖ monograph on Tilletia. The present combination was made by Schroeter.¶¶

*Norton. Trans. Acad. Sci. St. Louis. 7: 236.

†Hedwigia. 22: 2. 1883. Saccardo Syll. Fung. 7: 513.

‡Bull. Torr. Bot. Club. 12: 35. *pl. 25. 19-23.* See also Norton. Trans. Acad. Sci. St Louis. 7: 232.

§Winter. Bull. Torr. Bot. Club. 10: 7.

‖Curtiss. Cat. N. Carolina. 123. Syll. Fung. 7; 466.

¶Ravenel. Fungi. Car. 100. Berkeley. Notices of No. Am. Fungi. 573. Grevillea. 3: 59.

**Flora Crypt. Germ. 2: 213. *1661*, 1833.
Rabenhorst. Fungi Europ. 1697.
Hedwigia *12*: 152. Winter die. Pilze. 1: 109.

††Pflanzenkrankheiten. 185.

‡‡Krankheiten der Pflanzen. 118. *f. 20-21.*

§§Pflanzenkrankheiten. 325.

‖‖Bull. Miscel. Inf. Kew. 1899: 141.

¶¶Bemerkungen und Beobachtungen ueber Ustilagineen. Cohn. Beitrage zur Biogie d. Pflanzen. 2: 365, 1888.

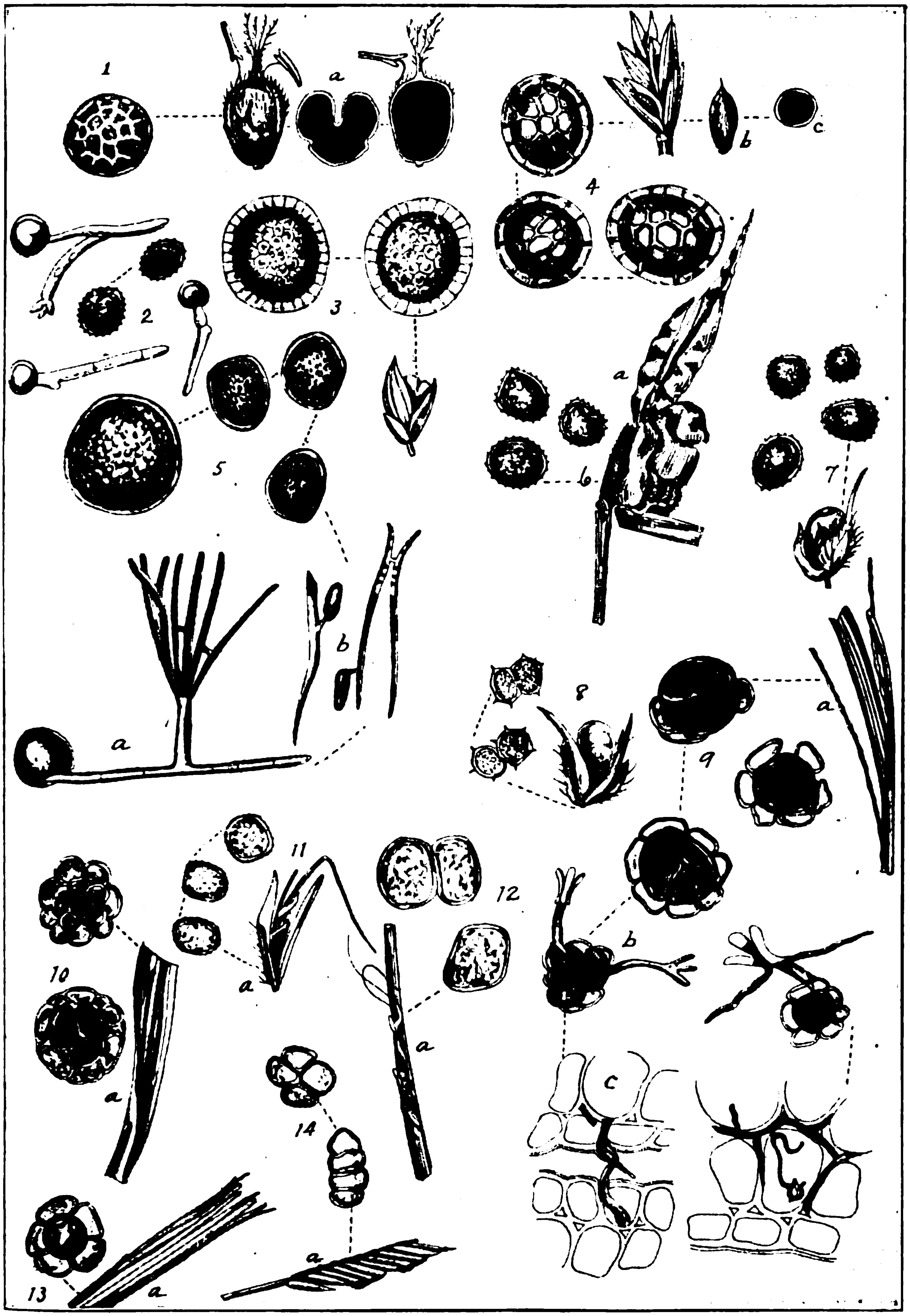

Fig. 120. *1*, **Wheat Bunt** (*Tilletia tritici*); *2*, **Timothy Smut** (*Tilletia striaeformis*); *3*, *Tilletia rotundata*; *4*, *Tilletia controversa*; *5*, **Wheat Bunt** (*Tilletia foetens*); *6*, **Barnyard Smut** (*Ustilago crus-galli or Cintractica*); *7-8, Sorosporium bullatum; 9, Urocystis occulta; 10, Urocystis agropyri; 11-12, Ustilago; 11, Sorosporium ellisii* var. *occidentalis; 12, Sorosporium ellisii* var. *provincialis; 13, Urocystis agropyri* on *Bromus ciliatus; 14, Cerebella spartinae* on *Spartina*. (Pammel and King)

This bunt is widely distributed in Europe and America. In the United States it is common in Wisconsin, where the writer found it in considerable quantity in the vicinity of La Crosse. It is reported by Trelease.* It is common in Indiana, according to Arthur.† It is likewise common in Ohio, according to Hickman,‡ and in Nebraska, according to Webber.§ Halsted‖ reports it as injurious to wheat in New Jersey. Kellerman and Swingle¶ have studied, more than other persons in this country, its nature and distribution in Kansas and the country at large. Swingle has also published several important papers on the subject.

It is not common in Iowa, though it has been found several times by the writer on the college grounds since 1891, and it has been found abundantly in the wheat screenings of some of our local mills.

General characters—It is not always an easy matter to tell the presence of this smut by the character of the plant, although the heads are darker green, appearing as though stimulated by an extra amount of fertilizer When the grain is ripening the diseased plants are recognized, the smutted heads having a paler color instead of the characteristic golden color of good wheat. The chaff is more spreading and the kernels are greatly swollen. One cannot be deceived by this disease when the kernels are crushed, for a very disagreeable odor is given off. According to Swingle, a whole bin of wheat may be charged with it. It is said by people who have followed the threshing machine that this odor is very pronounced where the disease is serious. I have myself noticed the bad odor in passing along the side of a field in western Wisconsin where the fungus was abundant.

Microscopic characters.—The spores of this fungus are nearly round or somewhat elliptical, smooth, 15–22 x 15–20^{u} in diameter. Under favorable conditions of heat and moisture the spores germinate in the course of a few days, by producing a promycelium. This tube produces, in the presence of oxygen,

*Parasitic Fungi of Wisconsin. 35

†Bull. Ind. Agrl. Exp. Sta. 28.

‡Bull. Ohio Agrl. Exp. Sta. II. 3: 205.

§Bull. Neb. Agrl. Exp. Sta. 11: 70.

‖Rusts, smuts, ergots and rots. Separate from Rep. New Jersey State Board of Agrl. 1889.

¶Bull. Kansas Agrl. Exp. Sta. 12: 1890.

The grain smuts, their causes and prevention. Yearbook U. S. Dept. Agrl. 1894: 409.

The grain smuts. U. S. Dept. Agrl. Farmers' Bulletin. 75: 6.

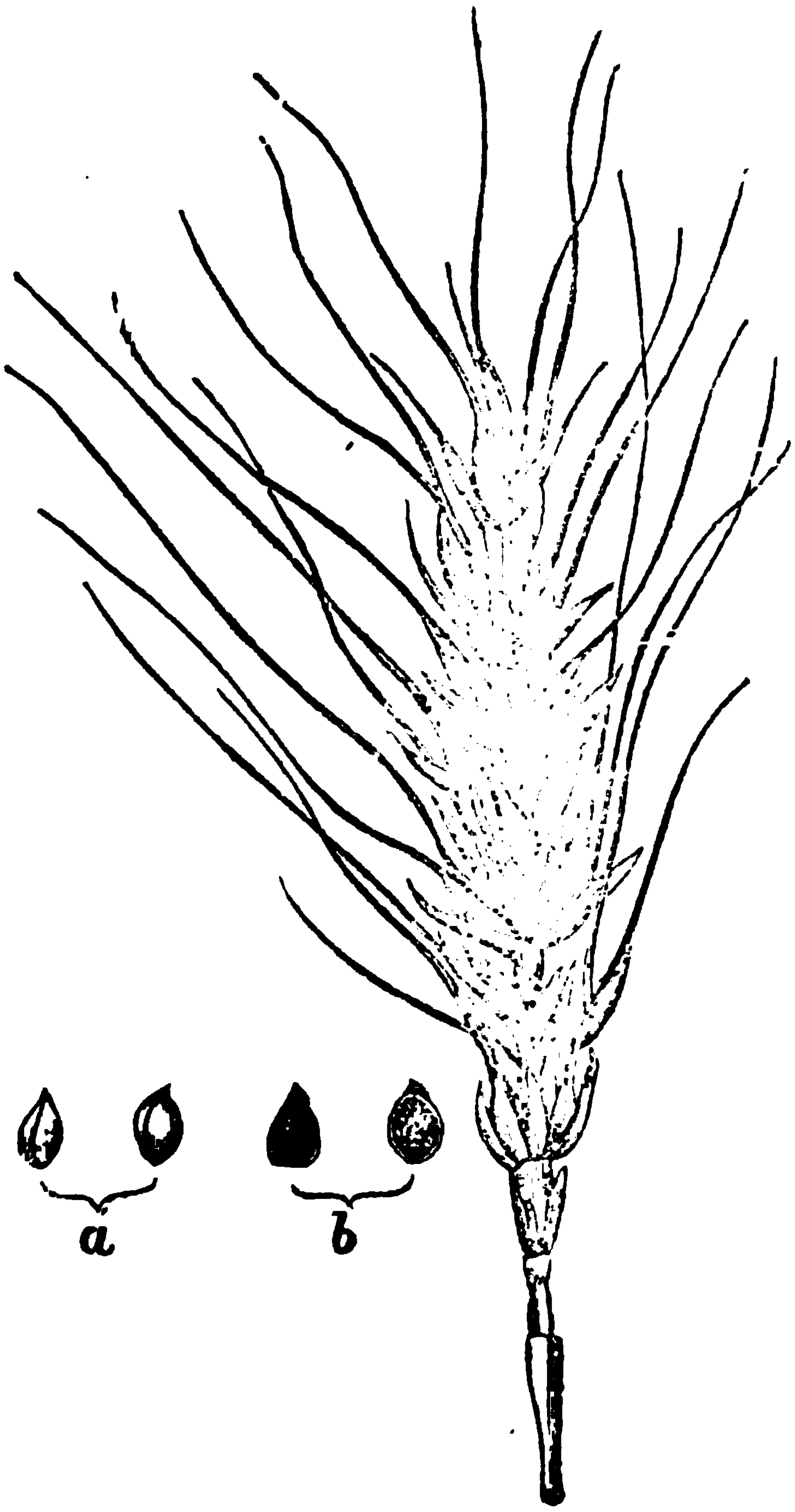

Fig. 121. Bunt of wheat, *Tilletia foetens*, after Bessey.

a whorl of slender bodies—the primary sporidia. These sporidia produce short tubes which join them to each other. The infection may result from the slender threads produced by the primary sporidia, or from the secondary sporidia, which also produce slender threads. These germ tubes can enter the plant only by way of the delicate tissues of the seedling.

Damage.—It is difficult to estimate the amount of damage. The percentage in Iowa is usually very small, but in Wisconsin I have seen whole fields destroyed, and Arthur* likewise gives an illustration where one-half of the crop was lost.

*Bull. Ind. Agrl. Exp. Sta. 28.
l. c. Farmers' Bull. 75: 6.

Swingle says: "There are no accurate statistics as to the amount of damage caused by them. In many localities, however, the losses are very great, and without doubt the losses in the entire United States amount to many millions of dollars annually. In some fields 50 and even as high as 75 per cent of the heads are smutted, and in addition the healthy grain is so contaminated with the fetid spores as to be almost worthless for flour and worse than useless for seed."

Tilletia tritici (Bjerk) Winter.—This species is more commonly referred to by European writers than the *T. foetens*. Thus Tubeuf,* Frank,† Loverdo,‡ Sorauer,§ Plowright,‖ Wolf and Massee¶ all mention its common occurrence in Germany, France and England. In the Mississippi valley it does not appear to be as common as the specimens above described. Bessey** reports this species as occurring in Iowa in 1884 and since. Harwood has reported†† it as common in Michigan. Kellerman and Swingle‡‡ report it in Kansas. In a general way this fungus is much the same as the former species. Harwood notes that wheat attacked by this species has shorter stalks than the normal. It affects the kernels and the chaff, spreading as in the last species. The spores are smaller, globose, with net-like ridges, 16–20^{u} in diameter. This last character easily distinguishes this form from the other smut. Its life history is the same. All of the heads of a stool are affected.

In European mycological works it is usually referred to as *T. caries*, by Sorauer, Frank and others. Tubeuf and Saccardo§§ refer to it as *T. tritici*, while Massee, in his revision, places it under the name of *T. caries*.

Tilletia secalis (Corda) Kuehn.—Bunt of rye was described by Kuehn‖‖ in 1876. Though quite destructive in Europe, Germany and Bohemia, it has not been found in this state. The kernels are filled with a brownish-black powder. Like the

*Pflanzenkrankheiten 318.

l. c. Krankheiten der Pflanzen. 117. (2 Ed.)

†Les Maladies. Crypt. 86.

‡Pflanzenkrankheiten. 185.

§British Uredineæ and Ustilagineæ. 283.

‖Der Brand des Getreides seine Ursachen und seine Verhutung. 12. Halle.

¶Wolf and Massee. Kew. Bull. of Miscel. Inf. 1899: 142.

**Bull. Iowa Agrl. Coll. Dept. Bot. 1884: 119.

††Bull. Michigan Agrl. Exp. Sta. 87: 5.

‡‡Preliminary experiments with fungicides for stinking smut of wheat. Bull. Kans. Agrl. Exp. Sta. 12.

§§Syll. Fung. 7: 481.

‖‖Bot. Zeit. 1876: 470.

other bunts, it produces a disagreeable odor. The spores are spherical or very rarely elliptical, usually 20ᵘ in diameter.

Tilletia hordei (Koernicke).—Bunt of barley was described by Koernicke* in 1877 from specimens found in Persia on *Hordeum fragile* as well as on *H. murinum*. This smut occurs in the ovaries and is covered by a blackish-brown membrane. The spores are smaller than those of *T. secalis*, measuring 19.5–20.5ᵘ in diameter.† The epispore is but slightly thickened, and reticulated.

Tilletia Lolii, Auersaw.—This bunt occurs in the fruit of *Lolium temulentum*‡ and other species. Spores are spherical or irregularly spherical or rarely elliptical; pale yellow or yellowish-brown, 17.57–20 by 24ᵘ in length, usually 19. Epispore with prominent projections which form a net work, the meshes of which, according to Winter. are 3.5ᵘ in width. The allied *T. controversa*, Kuehn, attacks the ovaries of *Agropyron repens;* the globose spores are pale brown. The mycelium is perennial in the rhizome of its host.

Tilletia rotundata (Arth) Ell.& Ev.—In South Carolina a Tilletia has been found quite abundantly on rice It affects the ovaries, converting them into a black granular mass According to Anderson§ who has studied the disease, the ovaries are seldom hypertrophied or atrophied, but retain to a great extent the form and size of the normal ovaries. The large, spherical, spiny spores are surrounded by a hyaline envelope. They are from 26–30ᵘ in diameter. According to Tracy and Earle this fungus occurs on various wild grasses like *Panicum virgatum* and Leersia. This is synonymous with *T. corona*, Scribner.‖ Massee evidently overlooked the American studies of the species. A second species, the *T. oryzae*, Pat.,¶ occurs on rice in Japan. The globuse or ovoid spores are olive-brown and warted; united into hard blackish-green mass. This belongs to Brefeld's Ustilaginoidæ.

Tilletia Moliniæ (Thum) Winter.—This species was first described by Von Thumen** as *Vossia Moliniæ*. Koernicke†† changed it to *Neovosia Moliniæ* (Von Thum) Kornicke, but Sac-

*Mycologische Beitrage. Hedwigia. 16: 30.
†Saccardo. Syll. Fung. 7: 484. Frank. Krankheiten der Pflanzen. 427 (2 Ed.)
‡Saccardo Syll. Fung. 7: 483. Winter. Die Pilze 1: 109.
§Bot. Gazette. 27: 467. 1899.
‖Bull. Torr. Bot. Club 23: 210.
¶Bull. Soc. Myc. 3: 124. 1887.
Saccardo Syll. Fung. 9: 286.
**Oest. Bot. Zeitscher. 29: 18.
††Syll Fung. 7

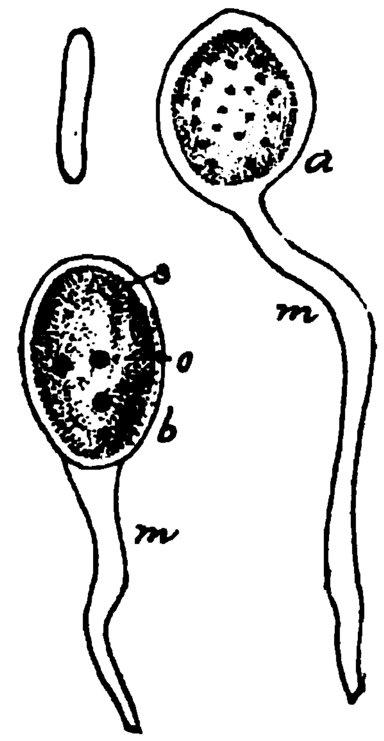

Fig. 122. *Tilletia molinae* on Phragmitis; *a*, spore; *m*, pedicel; *o*, oil bodies. (King)

cardo* and Winter place it under *Tilletia Moliniæ* (Von Thum) Winter. Dr. Farlow, who identified the fungus for me on Phragmitis, states that it seems to agree with that species. It was found by Mr. E. R. Hodson in considerable quantity on *Phragmites communis* in the vicinity of Colo. The ovaries are enlarged, much longer than broad. The interior is filled with a black powdery mass, the spores. The spores are round or elliptical, seldom spherical, dark brown in color, rough, and surrounded by a persistent thick-walled colorless exospore, with the permanently attached mycelium at one end, resembling a slightly twisted pedicel. Massee,† in his recent monograph of Tilletia, excludes this species from the genus Tilletia. The spores measure 16.6 to 20.8 x 24.9 to 29.1. It may be a good species but cultural experiments will be necessary to determine this point. In Europe it occurs on *Molinia cærulea.*

TIMOTHY SMUT.

This fungus (*Tilletia striaeformis* (Westd.) Magnus) has been known for a considerable length of time. It affects several different species of grasses. It was first described as *Uredo striiformis*, Westd.‡ The proper name for the fungus was given it by Magnus.§ This fungus has been quite abundant for a number of years in Wisconsin, Missouri and Iowa. The first economic account of it was given by Trelease in his paper on the smut of timothy.‖ He reported it as common in Wisconsin on timothy and that it also occurred on *Agropyron repens* and wild rye (*Elymus canadensis* var. *glaucifolious*). The writer gave a short account of the fungus in a series of papers on Fungus Diseases of Iowa Forage Plants,¶ referring to its common occurrence on timothy and *Agropyron repens*, both in this state and in Massachusetts. Since then the writer has frequently found it on blue grass and timothy in this state. In Europe the fungus is quite common on a number of different hosts, namely, perennial rye grass (*Lolium perenne*), tall meadow oat

*Winter die Pilze 1: 109.

†Bull. Miscl. Infor. Kew. 1899: 156.

‡Westend. Bull. Acad. Brux. 1851: 406.

§Winter Die Pilze 1: 108. For other references see Saccardo. Syll. Fung. 7: 484. and Plowright Mon. British Bred. and Ustil. 284.

‖Rep. U. S. Dept. Agr. 1885: 87.

¶9. See also Jour. Myc. 7: 97.

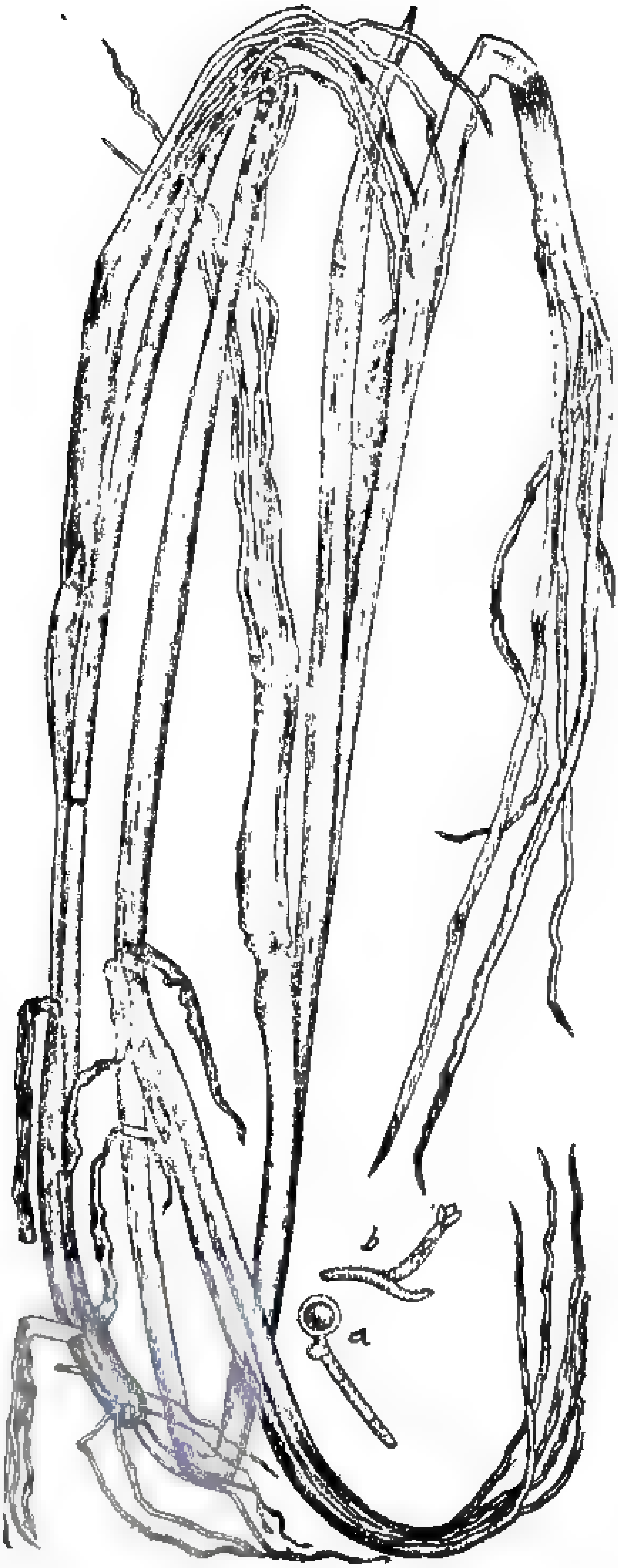

Fig. [illegible]. Timothy smut (*Tilletia striaeformis*) affecting timothy. Leaves torn up into shreds; *a*, spore germinating; *b*, promycelium with sporidia at the end. (King and Pammel.)

grass (*Arrenatherum avenaceum*), *Bromus inermis*, sheep's fescue (*Festuca ovina*), tall meadow fescue (*Festuca elatior*), etc

The fungus is closely related to stinking smut of wheat. The spores germinate in the same way and probably enter its host when the seed germinates. There is this important difference between the two species, this smut does not affect the "seed" in the same way. Its life-history is also somewhat different. The stinking smut is at most very short-lived, while this species is certainly a perennial. The destructive work of stinking smut comes on at a time when flowers and seed are forming. *Tilletia striaeformis* appears long before, perhaps soon after the first leaves come out early in spring. In Iowa I have noticed it about the middle of May; it continues, however, to develope on the younger leaves till the middle of June, when often the bracts of the flowers become affected. Last spring in one of the meadows on the college farm a large number of young plants were affected; the loss was very considerable. The plants were shorter and marked with longitudinal lead colored stripes, often extending to the very tips of the leaf. When these lead colored patches are torn open a black powdery mass, the spores, are exposed.

As the plants become older the epidermis of these lead colored patches breaks and thus exposes the spores. The constant action of the wind soon causes the leaf to be torn up into shreds. The affected plants never become so tall as the adjoining ones, seldom fruiting well. I think there can be very little doubt that the fungus is a perennial as the following will illustrate. During the spring of 1887 and 1888 I observed a small bunch of timothy in the Missouri Botanical Garden at St. Louis, every leaf and stalk in the bunch was affected. Both seasons it was found on the same plants. Here at Ames, also, I have seen the smut on the same plants for two seasons.

THE GENUS UROCYSTIS.

This genus contains several parasites destructive to our cultivated plants. Our grasses are effected by two of these, the rye smut and the wild rye smut.

RYE SMUT.

This fungus (*Urocystic occulta*, Wallr.), first described by Wallroth* in 1883, has been repeatedly observed in various European

*Fl. Crypt. Germ. 2: 212. Erysibe occulta, Urocystic occulta (Wallr.) Rabenh. Klotzsch Herb. Myc. No. 393. Fung. Eur. 1790.

countries by Sorauer,* Frank† and others. It also occurs in Australia where it is said to do much damage. It was first found in this country by Underwood‡ and Cook, who distributed the fungus, and later in Connecticut by Thaxter.§ It is not nearly so common in Europe as other cereal smuts and to my knowledge has never been found in Iowa.

It is stated that between the years of 1850 and 1860 it was so destructive in parts of South Australia that in some localilities cultivated rye sustained a loss of 66 per cent. Like timothy smut it attacks the leaves, sheaths, stem, and inflorescence, but generally it is found on the leaves and sheaths. It makes its appearance about the middle of May and continues through June. It is characterized by lead colored patches which are arranged in parallel rows along the veins. The epidermis which covers the sori soon becomes ruptured and exposes the powdery spores, and like timothy smut, the leaf is soon torn up into brown shreds The spores differ very materially from any we have thus far considered. They are arranged in clusters made up of two kinds of cells. The central ones are darker in color, and are capable of germination; the surrounding cells are lighter in color and do not germinate. The Urocystis spores do not germinate very readily. The promycelium bears the sporidia at the end. The fungus enters its host through the very young leaves close to the seed. Wolff states that the fungus cannot enter later. In eight or nine weeks rye, inoculated with sporidia, produced spores in the seventh or eighth leaf. When the sporidia come in contact with the leaf they attach themselves very closely, penetrate the cuticle of the epidermal cell, growing crosswise through the young seedling and then passes from the inner epidermal cell of one leaf to the outer of another. The mycelium when once in the interior of the plant grows in the intercellular spaces, sending haustoria into the cells.

WILD RYE SMUT.

This smut, *Urocystis agropyri* (Preuss), Schr., occurs on several grasses in Europe and the United States.‖

*Pflanzenkrankheiten. 190.
†Krankheiten d. Pflanzen. 121 (Ed. 2).
‡A Century of Illustrative Fung. No. 57. 1889.
§Rep. Conn. Agrl. Exp. Sta. 1899: 143. *pl.* 2. *f.* 9-10.
‖Saccardo. Syll. Fung. 7: 516.
Farlow and Seymour. Hort. Index. 150.
Tubeuf. Pflanzenkrankheiten. 329.

In Massachusetts the writer found it common on *Agropyron repens*, and it is reported on the same host in Europe by Tubeuf. It is also reported on tall meadow oat grass and *Festuca rubra* and *Bromus inermis*. Thus far it has only been observed by me on the wild rye, *Elymus robustus*. This species is very common about Ames. It makes its appearance early in June and continues through July. Hundreds of culms are affected. In many cases it is difficult to find a sound leaf in some places. The fungus is characterized by linear lead-colored patches, which occur along the veins of the leaves. On drying them the epidermis becomes ruptured, exposing the black powdery spores, which have much the same character as the rye smut, measuring 1–3 x 8–12ᵘ in diameter. The spores do not germinate readily. It is certainly a perennial. The species was first described from European specimens.*

TREATMENT FOR SMUT.

All smuts are not amenable to the same treatment, since the manner of entering the host differs. In many diseases of plants hygienic methods are of much value, and to some extent these are of value also in smuts. Of course, in the case of corn smut, much can be done by removing the smutted portions of the plant, and rotation of crops should always be practiced. Though this will destroy but a small portion of the smut, it is helpful. Use care in seed selection—the seed should be free from smut. In the way of treating the seed, two methods have been in vogue—hot water and the chemical treatment. The latter has been in vogue for a long time, especially the method of treatment with blue stone. For full accounts Swingle's† papers should be consulted.

Formalin.—During recent years much has been said about formalin as an antiseptic as well as a disinfectant. Experiments made by Close‡ and Bolley§ indicate that it is valuable to prevent stinking smuts, as well as loose smut of oats. It is used at the rate of one pound to fifty to sixty gallons of water, and the seed soaked two hours. The 40 per cent solution should be used. The strong solution is poisonous; the dilute solution is not dangerous. A one per cent solution gave good results.

**Uredo Agropyri*. Preuss in Klotzsch Rabh. Herb. Myc. *1696*.
Urocystis Agropyri (Preuss) Schr. Brandu. II. Restp. Schl. 7.
†Yearbook U. S. Dept. Agrl. 1894: 415.
Farmers' Bull. Office of Exp. Station. U. S. Dept. Agrl. 75.
‡Rep. N. Y. Agrl. Exp. Sta. 16. 294. 1897.
§Bull. North. Dak. Agrl. Exp. Sta. 27.

Potassium sulphide.—Potassium sulphide has proved efficacious. The method given by Swingle is as follows: "Dissolve one and a half pounds of potassium sulphide in twenty-five gallons of water in a wooden vessel (a tight barrel serves very we'l for this purpose). The potassium sulphide should be of the fused form, known as liver sulphur. This can be obtained of any druggist for from 25 to 50 cents per pound, according to the quantity purchased. It should be kept protected from the air in a tight glass vessel until ready for use. The lumps of potassium sulphide dissolve in a few minutes, making the liquid a clear yellowish-brown color. After thoroughly stirring, put into the solution about three bushels of oats and agitate well to insure wetting every grain. The solution must not only cover the grain, but must rise several inches above it, as some of it is soaked up by the grain. Leave the oats in the solution for twenty-four hours, stirring several times during the day to make sure that every kernel is wetted, after which spread out to dry. A number of experimenters have found that soaking the seed two hours in a 2 per cent solution (eight pounds to fifty gallons) was nearly or quite as effective as the longer treament. The grain should be stirred repeatedly to insure thorough wetting. Seed thus treated is much easier to dry than that soaked twenty-four hours. Probably this form of treatment will prove the best.

"In treating large quantities of seed a hogshead or wooden tank might be used. The solution should be kept well covered to keep the air from it, and should not be used more than three times. In no case should metal be allowed to come in contact with it. This treatment is thoroughly effective for loose smut of oats, and is worthy of a trial for stinking smut of wheat."

Ceres powder.—This substance is advertised as a preventive of smuts, is, according to the analyses of Hollerung and other German investigators, only crude potassium suphide sold under another name and at a much higher price.

Sar solution.—This consists chiefly of sodium sulphide and as given by Swingle is prepared as follows: "Place fifteen pounds of flowers of sulphur in a barrel, mix thoroughly with one-half pound of finely-powdered resin, and stir well with three quarts of water, which should make a thick paste. The paste must not be thin and watery, nor so dry as to crumble to powder when stirred. Then add ten pounds of caustic soda

and stir well.* After from three to fifteen minutes the mass turns a reddish-brown and boils violently, and must be stirred well, preferably with a broad paddle, to prevent it from running over. After it has ceased boiling, add about two gallons of water (hot if possible, but cold will do) and then carefully pour off into another vessel marked to ho'd six gallons, and add hot wa'er till the six-gallon mark is reached. This gives a stock solution, which must be kept in tightly closed jugs or in closed barrels or kegs, since it boils if it comes in contact with the air. It is also decomposed if it touches metals. Of this stock solution use one and one-half pints to fifty gallons of water, soaking the seed twenty-four hours, or one gallon to fifty, soaking two hours. In either case treat the seed according to the directions given for the potassium sulphide treatment."

Hot water.—Numerous experiments by Jensen, Arthur, Kellerman and Swingle, Jones, the writer and many others have shown that hot water is efficacious as a preventative for oats smut and bunt.

Provide two large vessels holding at least twenty gallons each (two wash kettles, soap kettles, wash boilers, tubs, or even barrels will do). One of these vessels should contain warm water at say 110° to 120° F. and the other hot water at 132° to 133° F. The first is for the purpose of warming the seed before dipping it into the second, un'ess this precaution is taken it is difficult to keep the water in the second vessel at the proper temperature. A pail of cold water and a kettle of boiling water should be kept at hand to draw from when necessary to raise or lower the temperature; or, better still, in case a kettle or boiler is used, the temperature of the water may be kept up by placing the vessel over a small fire. Where steam is available, it can be conducted into the second vessel containing the hot water by means of a pipe provided with a stopcock. This answers better than any other method for heating the water and for elevating the temperature from time to time.

Place the seed to be treated, at the rate of half a bushel or more at one time, in a closed vessel which will allow the free entrance of water on all sides. A bushel basket made of heavy wire, with wire netting, say twelve meshes to the inch, to spread inside, may be used for this purpose; or a frame can be

*"Finely-powdered concentrated lye sold in grocery stores in one-pound packages, such as Red Seal granulated lye, serves admirably. If considerable quantities of the solution are to be prepared, it will be cheaper to purchase powdered caustic soda, 98 per cent pure, in ten-pound tins, through some wholesale dealer in drugs or chem'cals."

made at a trifling cost and the wire netting stretched over it. This will allow the free passage of the water and at the same time prevent the seed from passing out. A sack made of loosely woven material—for instance a gunny sack—may be used instead of the wire basket. In some respects a perforated tin vessel is preferable to any of the above. It is important not to fill the baskets or sacks completely, as the grain is wetted more easily, drains better, and is more uniformly exposed to the hot water when it can move about freely. It is also important to have a volume of hot water at least six to eight times as great as the capacity of the basket or sack; otherwise the temperature varies too much.

Copper sulphate.—This has long been used for the treatment of oats smut and bunts. It is used in the following proportions: Dissolve one pound of copper sulphate in twenty-four gallons of water; immerse for twelve hours. After this immersion Swingle recommends to place the seed for five minutes in lime water made by slacking one pound of good lime and then diluting to ten gallons with water.

Corrosive sublimate.—This well known disinfectant has been recommened by Bolley* for bunt, in the proportion of one pound to fifty gallons of water. The following are the directions given for applying this treatment: "Pile the wheat upon the floor or upon a canvass and thoroughly sprinkle or spray on the solution, while the grain is being constantly shoveled over so that every grain becomes wet over its entire surface. Do not use any more of the solution than necessary to do this, as an excess is injurious to the seed." The writer has found it efficacious to prevent oats smut. It should be constantly stirred, and care used not to use too much of the liquid; too long contact greatly impairs germination. In this method great care should be used, as the solution is very poisonous.

The potassium sulphide treatment, as well as the hot water method, show that there is an increase in the yield. Arthur states that hindered germination is due to the liberation of large quanties of diastase by the action of heat.

RUSTS, OR UREDINEÆ.

The term rust as applied to cereals is usually pretty well understood by most people, though the term is often incorrectly applied to many other fungi. The term is limited to a class of

*Bull. North Dak. Agrl. Exp. Sta. 27.

Fig. 124. Rusts of grasses. *1*, Spartina rusts (*Uromyces acuminatus*) on spartina cynosuroides; 2, teleuto spores of orchard grass rust (*Uromyces dactylidis*) uredo spores at *a*; *3*, teleuto spores of *Uromyces poæ*, uredo spores at *a* on Poa; *4*, *Puccinia coronata* on *Rhamnus cathartica*; *5*, aecidium of *Puccinia graminis* on barberry, *a* and *b*, spores magnified; *6*, *7*, *Puccinia graminis*; *8*, aecidium of *Puccinia graminis*, the cup below spermogonia above *b* spores, *a* peridial cell. (Pammel and King.)

fungi belonging to the Uredineæ as will be made clear in the following pages. The Uredineæ are among the most destructive of the parasite fungi of cultivated and wild plants. Well-known illustrations are, cereal rusts, rust of apple, coffee leaf disease, hollyhock rust and carnation rust. The rusts are common on a large number of grasses. The most important of those affecting Iowa forage plants will be taken up under the head of (1) rusts of cereals, (2) rusts of other grasses.

History —Rust was well known to the ancients. This affection is mentioned in connection with smut. It is referred to in several places in the Bible.* Aristotle mentions its occurrence and causes. Plinius, Columella, Ovidius and other writers mention the occurrence of rust. But little mention was made of it during the middle ages, though beginning with the seventeenth century reference to it became frequent. Some of the laws looking toward the extermination of the barberry date from 1660 when an act having that object in view was passed in Rouen. In 1755 Massachusetts passed a law looking towards the extermination of the barberry. A complete and full history will be found in the work of Eriksson and Henning.

RUSTS OF CEREALS.

The subject of rusts is one of special interest to us because large losses are usually entailed by our cereal crops. During the last decade several wheat crop failures in parts of our state have been caused by rust. It is, therefore, proper that this subject should receive consideration.

Eriksson and Henning,† in their recent monograph, find that our cereals have several specialized forms of rusts. Carleton,‡ as the result of some careful studies, finds that our cereal rusts are specialized.

*5 Moses 28: 22. 1 King 8: 37. 2 Chro. 6: 28.

†Die Getreideroste ihre geschichte und natur sowie Massregeln gegen dieselben. Stockholm. 464. *pl. 13. map I. f. 5.* 1896.

‡Cereal Rusts of the United States. Bull. Div. Vegetable Phys. and Path. U. S. Dept. Agrl. 16.

The following outlines show the chief cereal rusts and their host plants:

Maize (*Zea mays*),	*Puccinia sorghi*, Schw.
Wheat (*Triticum vulgare*),	*Puccinia graminis*, Pers. f. *tritici*.
	Puccinia glumarum (Schmidt) Eriks. & Henn. f. *tritici*.
	Puccinia rubigo-vera (D. C.) Wint. f. *tritici*.
	Puccinia dispersa, Eriks. & Henn.
Oats (*Avena sativa*),	*Puccinia coronifera*, Klebahn.
	Puccinia coronata.
	Puccinia graminis. f. *avenæ*.
Barley (*Hordeum vulgare*),	*Puccinia graminis*.
	Puccinia simplex, Koernicke.
	Puccinia glumarum. f. *hordei*.
Rye (*Secale cereale*),	*Puccinia graminis*. f. *secalis*.
	Puccinia glumarum. f. *secalis*.
	Puccinia rubigo-vera. f. *secalis*.

Eriksson and Henning use the name *P. dispersa* for the old *rubigo-vera*, which has been in use among mycologists for a long time. Carleton, after having made a careful morphological study of the rusts of northern Europe and the United States, concludes that the *P. dispersa* and *P. rubigo-vera* are identical, and that the name *P. rubigo-vera* should be used.' He concludes that we have six cereal rusts and a possible seventh in the United States.

CORN RUST.

Corn rust (*Puccinia sorghi*, Schw.) Schweinitz,* an early American mycological writer, described this fungus as early as 1834, but earlier than this Carradori † an Italian writer, referred to this fungus. It is widely distributed, occurring where corn is cultivated, and at times is quite troublesome, especially in North America. According to Saccardo,‡ it occurs in Italy, France, Austria, Germany, Lusitania, North and South America. Peck§ and Seymour‖ have given us the only early economic accounts of the fungus. There is also a

*Synop. Fung. 295.
†Giorn Fis. Pavia. 8. 1815.
‡Syll. Fung. 7: 659.
§Rep. St. Mus. of Nat. Hist. N. Y.. 34: 29.
‖U. S. Dept. Agrl. Report. 1887: 389.

short account by one of us,* and one by Weed† in his book, "Fungi and Fungicides."

Characters of the fungus.—The fungus produces two stages. The first or uredo stage is similar to the red rust stage of wheat. It occurs on the bracts covering the cob, leaves and sheath. Small, light-brown pustules or sori appear on both surfaces of the leaf. Close examination will show that these sori break through the epidermis where small white spots occur. The rupturing of the epidermis is caused by the continued growth of the spores underneath. The ruptured epidermis shows the small spores. The uredo spores are one-celled, round or more often elongated and spiny. The stalk is detached. The spores measure 23–38 x 20–26^{u}. The uredo sori are clustered or arranged in parallel rows, closely following the veins of the leaf. The uredo spores are capable of germinating immediately and distribute the fungus during the summer. They preserve their vitality for only a short time; at any rate they do not live through the winter. Carleton‡ states that the time of incubation for the uredo is shorter than any of our cereals, varying from five to eight days.

As the leaves become older the yellowish-brown uredo sori are replaced by black sori. These sori may also appear where uredo sori did not occur. The same mycelium which gave rise to the uredo spores later gives rise to the teleuto spores. The sori containing these spores are black. The spore is broadly elliptical and two-celled. It measures 30–52 x 16–24^{u}. The apex may be thickened and somewhat pointed. These spores preserve their vitality for some time; they are dormant through the winter. In the spring each cell may germinate by producing a tube, known as the promycelium, which bears laternal bodies known as sporidia. It is undoubtedly connected with some æcidium or cluster cup stage, but this stage is not known. Carleton reports the occurrence of this fungus on Teosinte (*Euchlaena mexicana*) which is closely related to maize.

The species is of considerable economic importance in our state, but it is seldom that reference is made to it. Duthie and Fuller§ state that corn is singularly free in India from fungus diseases. Agricultural writers in this country do not usually

*Pammel. Monthly Review of the Iowa Weather and Crop Service. 7: 7. 1896.
†Weed. Fungi and Fungicides. 207, *8*, *86*.
‡Cereal Rusts of the United States. 66.
§Field and Garden Crops of Northwestern Province. Ouah. etc. 1: 21.

Fig. 125.

Fig. 127.

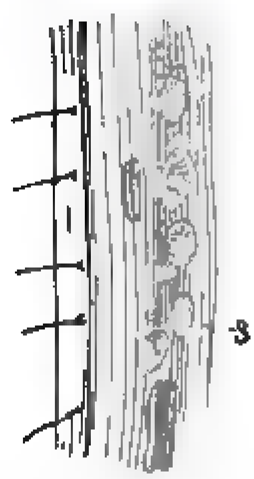

Fig. 128.

Fig. 126.

Fig. 125. Teleuto sori of *Puccinia graminis*.

Fig. 126. Uredo sori of *Puccinia coronata* leaf of oats, sheath affected with *Puccinia graminis*.

Fig. 127. Maize rust (*Puccinia sorghi*). Teleuto sorus, magnified.

Fig. 128. Maize rust (*Puccinia sorghi*) on *Zea mays*. s, sorus.

refer to this disease, but on some varieties of corn it is very severe

We have seen this fungus so abundant as to seriously destroy the leaves and sheaths of corn, in fact so abundant as to materially injure the crop. This was especially true of some varieties of corn grown on the college grounds, the seed of which came from the Philippine is'ands. In this case, no doubt, unfavorable climatic conditions of that variety caused it to rust. It is more severe on sweets than on the dents. At times our field corn is very seriously affected.

Professor Seymour says: "The fungus is always injurious to the corn on which it grows, but the extent of the injury depends largely upon the age and condition of the corn and climatic conditions, and is often so slight as to be of no practical importance. Certain conditions of the weather may retard the growth of the corn and favor that of the rust. Ordinarily the rust is not noticed till the latter part of the summer, when the corn is well grown and not easily injured; but in the first week of July, 1886, the writer observed it repeatedly on the lower leaves of partly-grown corn, whose vigor was plainly impaired by it. The injury consists in loss of food materials elaborated by the plant for its own growth which the mycelium of the fungus uses for its growth and in destroying the power of some of the tissues of the plant to do its work.

COMMON GRASS RUST.

This rust (*Puccinia graminis*, Pers.) in several of its forms is common on many grasses and especially destructive to oats and wheat. The common rust produces three stages. One stage occurs in the barberry and is known as the cluster cup fungus. This stage makes its appearance in the northwest some time during the month of June. In the latitude of Ames, a little before the middle of the month. An examination of an affected leaf will show small black specks on the upper surface, surrounded by a yellow spot; this is known as the spermagonial stage; the flask-shaped bodies are called spermagonia and contain the spermatia. These do not germinate; their function is not known. A sweetish fluid, which attracts insects, is frequently found in connection with these. Directly opposite the flask-shaped bodies are small globular affairs, "cups," (Aecidia), slightly irregular on the margins. Owing to their upward growth they rupture the epidermal cells and finally the lining

layer of cells of the cups also break, thus exposing a large number of one-celled spores borne in chains. These spores arise from short stalks contained at the base of these cups; the cluster cup spores are known as aecidiospores. They are transported by the wind and other agencies, and have the power to germinate soon after maturity. When the proper host—a grass like bent grass, oats or wheat—occurs, the germ tube enters by way of the stomata, or the so-called breathing pores. The germ tubes produced by the spore of *Aecidium berberidis* are simple or branched, and in fourteen days usually give rise to the uredo spores, which occur in definite spots called sori. These spots occur in great number along the veins of the leaves. Before breaking open, the tissues of the leaf are somewhat paler at those places. The nourishment afforded by the host causes a vigorous mycelium to form, which soon collects in places, pushes the epidermis out, and an orange-colored pustule is formed; this is known as the uredosorus.

A section through a diseased sorus shows that an abundance of the vegetative mycelium grows between the cells of the plant, and in some cases haustoria penetrates them. This pustule contains a large number of one-celled, round or elliptical, spiny, orange-colored spores, the uredo spores. This spore has two membranes, the outer exospore being provided with wart-like projections. The inner endospore is provided with several pores through which the germ tube appears. These spores germinate in from three to four hours; they can thus start a general infection. These spores, carried by the wind, rain or insects to another part of the same or another plant, germinate. The germ tubes branch and spread over the surface, but the tube cannot enter the host, a grass of some kind, such as wheat, oats or barley, unless it reaches the opening of the stoma, since it cannot bore through the epidermal cells. A single sorus contains hundreds of spores, and as a single plant may contain hundreds of pustules, it can readily be seen that rust must become quite general.

The red rust stage is followed by the black rust stage, known as the teleuto stage. The sori are brownish-black in color, and frequently occupy the same place that the uredo stage did. The spores are dark brown in color, two-celled and smooth, having attached to them a persistent stalk known as the pedicel. The teleuto spores do not germinate till the following spring, when each cell produces a germ tube, the promycelium

bearing lateral spores, sporidia. These sporidia, when in contact with the barberry leaf, enter by boring their way through the epidermal cells.

The barberry cluster cup fungus, and its connection with common grass rust.—It is not absolutely necessary for the common grass rust to have its first stage on the barberry, yet experiment has shown beyond doubt that it does occur on that plant. The theory has been advanced that appearing in one of its stages on the barberry gives the parasite new vigor. It is not improbable that in some places the mycelium or vegetative part of the fungus may be perennial in the tissues of grasses, as it is with many other fungi, and I am inclined to think this is true in southern localities. Beyond question this rust produces spores during the entire year in our southern states, and on the approach of early spring gradually moves northward. I may also mention the fact that this rust certainly does not in the west appear before the cluster cup fungus on the barberry appears. It is usually eight or ten days later, and then only to a limited extent. Rust often appears where barberry does not occur within hundreds of miles. This was especially noticeable during the early history of grain culture in the northwest. Rust follows a general infection.

Grasses affected.—In addition to the cereal plants enumerated in the table, this rust has been reported on the following grasses: Bent grass, *Agrostis alba*, *A. capillaris*, *A. canina*, *Aira caespitosa*, *Alopecurus pratensis*, *Agropyron repens*, *A. spicatum*, *A. caninum*, *Avena fatua*, *Briza media*, *Bromus tectorum*, *Briza maxima*, *Bromus mollis*, *Calamagrostis*, *Dactylis glomerata*, *Distichilis maritima*, and Eriksson and Henning report it also on *Elymus canadensis* and several other forms; it has, however, not been seen by me on this host. We have repeatedly seen it on *Holcus lanatus* and *Hordeum jubatum*.*

It should be borne in mind that in many cases these hosts have not been determined by inoculation experiments. The inoculation experiments of Carleton show that the *P. graminis avenæ* are not successful when applied to wheat, but successful when applied to *Avena sativa*, *A. fatua*, *A. pratensis.*, *Dactylis glomerata*, *Arrhenatherum avenaceum*. The following are probable hosts: *Koeleria cristata*, *Ammophila arenaria*, *Bromus ciliatus* and *Loliam perenne*. The *Hordeum jubatum*, according to Carleton, supports two distinct forms of *P. graminis*. The same

*Bull. Iowa Agrl. Exp. Sta. 30: 303. 1895.

author states that the *Puccinia graminis tritici* occurs on cultivated varieties of wheat, *Hordeum jubatum*, and *H. vulgare*. The following spices also act as hosts: *Triticum spelta*, *T. dicoccum*, *Agropyron richardsoni*, *A. tenerum* and *Elymus canadensis*.

Eriksson and Henning and other writers* report this rust on several other species of *Hordeum*, *Koeleria cristata*, *Lolium perenne*, *L. temulentum*, *Agropyron tenerum*.

The cluster cup fungus occurs more commonly on the common barberry (*Berberis vulgaris*) because it is more commonly cultivated. I have also found it on *B. cerasisforme* and *B. canadensis* here at Ames. One species of barberry, *B. thunbergi*, is exempt here.

There is no evidence that the rust can survive the winter in the northern states; *i. e.:* that the mycelium is perennial in the tissues of wheat or grass. At least this does not occur in Iowa, and Professors Hitchcock and Carleton failed to find that it is perennial in Kansas. They state that it seems probable that *P. graminis* does not pass the winter in this vicinity in the uredo stage, nor in the mycelial condition. Whether or not it survives the winter further south is a question still to be answered. Eriksson and Henning state that in Stockholm and Sweden the uredo spores do not persist during the winter, and that infection does not result from these occurring in the fall. Cold weather is inimical to their development. The results of the Swedish writers are entirely trustworthy. It is claimed by Von Thumen for Austria, Plowright for England and Kuehn for Germany that this species is perennial. In Austria accord-

*Arthur, J. C. Notes on Uredineæ. Bot. Gaz. 16: 226. 1891.

Bolley, H. L. Wheat Rust. Bull. Ind. Agrl. Exp. Sta. 26: Wheat rust is the infection local or general. Agrl. Sci. 5: 259.

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Carleton, M. A., & Hitchcock, A. S. Preliminary report on rusts of grain. Bull. Exp. Sta. Kansas Agrl. Coll. Manhattan. 38: 1893. Cereal rusts of the U. S. Div. Veg. Phys. and Veg. Path. U. S. Dept. Agrl. 16.

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ing to Cobb the species grows during the entire year. Some years ago a systematic investigation was made of the rust affecting cereals in the vicinity of Ames. While *Puccinia graminis* was common in the fall, gradually disappearing on the approach of cold weather, none of the sori were found during the winter or early spring. It was not till the cluster cup fungus appeared that this rust commenced to appear. Some of the infested plants were removed to the green-house and developed rust in abundance during the winter.

COVERED RUST OF WHEAT.

We may now discuss briefly two species of rusts, the *Puccinia glumarum* and *P. rubigo-vera*, which are more or less common on wheat and some other grasses, and have very appropriately received the name of covered rust.

Puccinia glumarum.—Æcidium unknown; the uredo sori occur along the veins. The diseased leaf is frequently of irregular contour, color orange yellow, spores spherical, or short, elliptical, spiny. Teleuto sori, grayish, covered by the epidermis on the stalks and leaves, less frequently on the flowers. Sori divided into chambers, surrounded by paraphyses. Spores with short pedicels, mostly club-shaped, unsymmetrical; apex somewhat truncate, or with one or two projections. This rust does not seem to have been generally recognized as belonging to the description given by Schmidt in 1819. It has been usually referred to as *P. rubigo-vera*. It seems quite certain that most European mycologists who have been working with the economic side of this question have had the *P. glumarum* in mind. Eriksson and Henning say it is difficult to say from the diagnoses of many writers who have discussed this question whether they had *P. glumarum* or *P. dispersa*. In European mycological works the æcidium of this fungus is said to be very common on common speedwell (*Lithospernum arvense*) *Echium vulgare* and *Anchusa officinalis*. Common speedwell is a very common weed in St. Louis and other parts of Missouri and southern Illinois, but I have never found the æcidium on these weeds.

It is very evident from the researches of Eriksson and Henning* that most writers must have been working with a rust very different than *P. rubigo vera*. On the question of the relation of temperature and the appearance of this rust, Eriksson

*l. c. 146.

and Henning state from their extended observations that there are marked differences in the disposition of the rust, depending upon temperature conditions. It appears further from their researches that the amount of precipitation was important in the product'on of this rust. Concerning the ability of the uredo spores to pass the winter in a living state in northern climates, these writers found no evidence of it in the least, or at any rate the conditions for this are extremely unfavorable. It appears that in some cases where the snow covers the ground during the spring, with a few slight frosts, the mycelium may be carried over, but its occurrence in this way is not very common. On the other hand a long continued snow is likewise detrimental.

Puccinia dispersa.—This species of rust is apparently very common in Europe. There are three different stages The æcidium stage produces circular or elongated, somewhat swollen, spots on the leaves, petioles and stem of several members of the borage family. The spores are between 20 to 30" or 20 to 30 x 19 to 22". The uredo spores are spherical or short elliptical; pale yellow, 19 to 29" in diameter. The tuleuto spores long remain covered by the epidermis. The sori chambered, surrounded by numerous brown paraphyses; spores are mostly club-shaped, unsymmetrical. Spores 40 to 50" long. According to Eriksson and Henning the uredo spores can germinate in the fall. In addition to the above named hosts, this rust has been found on several species of *Bromus*, *Trisetum* and *Triticum spelta.* Its distribution cannot be given because in most cases the *P. rubigo-vera* included this as well as the *P. glumarum.* It has been intimated above that the uredo spores make their appearance on young germinating plants in the fall, but it appears that the uredo spores are not common the following spring. The investigations of the authors quoted here indicate that not in a single case was it possible to produce uredo spores in the spring from those of the autumn.

L. H. Bolley, of Fargo, N. D., well remarks in regard to several cluster cup fungi which occur on members of the Borage family: "Several æcidia of unknown life history have been studied with reference to their relations to the red rust of *Puccinia rubigo-vera,* many infectious tests being made upon young wheat and oat plants, all with negative results."

"In this region *Onosomodium carolinanum* bears very profusely an æcidium, which, because of its date of appearance, was worthy of suspicion; but tests enough were made to remove this notion." *P. rubigo-vera* as well as the common grass rust, is very destructive in England and Australia; according to Wolf, not so common in Germany. A few years ago Professor Arthur investigated the subject of wheat rust in Indiana and found that this species was much more destructive to wheat in that state than common grass rust. The same year, 1889, I found that this rust was much more common on our wheat. Carleton* says he is confident that the orange-leaf rust (*P. rubigo-vera*) does very little if any damage to the grain in this country; that in all cases of serious damage to the grain by rust the black-stem rust (*P. graminis*) is the real cause.

In 1891 and 1892 the rust under consideration was hardly as destructive as common grass rust. In 1893 covered rust was more abundant than common rust. Atkinson states that uredo spores develop during any month of the year, during the winter and spring attacking the grains, and during the summer and autumn the grasses, so that we may probably have a perennial infection from uredo spores, Bolley states that there are isolated cases in which the mycelium of this species may live in the tissues of the wheat during the winters. This, however, can occur only during the mild winters. I have been unable to verify this for the state of Iowa, and Bolley has, likewise, failed in North Dakota. Hitchcock and Carleton find that in the vicinity of Manhattan, Kan., the *Puccinia rubigo-vera* passes the winters in the tissues of the wheat plant in the mycelial condition. During the warm weather of spring a crop of spores is produced which, under favorable conditions, may rapidly spread the disease. The infection of the winter wheat in the fall is materially aided by the volunteer wheat, which carries the rust through the few months following harvest, and these results have been reconfirmed by Carleton† in Kansas and Maryland. According to Sorauer the mycelium is perennial in the parenchyma of the leaves of cereals. We are forced to the conclusion that infection is general and that our wheat suffers much from southern invasion of this parasite. No doubt the perennial character of the mycelium in warm climates plays an important part in spreading the disease. In northern states,

*Improvements in wheat culture. Year book U. S. Dept. of Agrl. 1896: 497.
†Cereal rusts. l. c. 21.

with severe winters, the mycelium, except under favorable conditions, is not perennial.

CROWNED RUST.

Puccinia coronata.—This is a well-known destructive rust of oats and several other grasses and has received considerable attention from early mycologists. Klebahn* has recently described this rust under several distinct forms. The *P. coronata dactylidis* in a narrow sence includes the rust upon *Dactylis glomerata* or orchard grass, *Festuca sylvatica* with æcidia on *Rhamnus frangula* and *P. coronifera*. Ericksson and Henning distribute these forms into *P. coronata* I, and *P. coronata* II. Historically this rust is of considerable importance, since Gmelin† was familiar with this disease in 179', and described it as *Aecidium rhamni* on Rhamus. Other early mycologists described the fungus, as Persoon, Schumacher, Lamarck and DeCandolle. The *Aecidium rhamni* Gmel. produces round or elongated spots with elongated, conspicuous æcidia. The spores from 18 to 25u by 14 to 19u. The uredo sori are long, confluent, mostly on the upper surface of the leaves, seldom on the under surface of the leaf. They are orange-colored, and are soon exposed. Each pustule contains a large number of one-celled, sub-globose, roughened spores. The spores are spherical or short, elliptical. The plant is yellow, 20 to 32u in diameter by 28 to32u by 20 to 24u. The teleuto spores remain covered by the epidermis, and in this respect they resemble the covered rust of wheat (*Puccinia glumarum*). They usually occur on both sides of the leaf. The spores are short stalked, cuneate and more or less truncate above, crowned with several projecting horns. The æcidium stage occurs on a species of buckthorn (Rhamnus) especially (*R. Cathartica* and *R. frangula*). In this state an æcidium is frequently found on a native buckthorn (*R. lanceolata*), but its connection with this host has not been studied. The æcidium attacks not only the leaves, but occurs on mid-vein, petiole, pedicels and flowers. As a result of the attacks, distorted leaves and flowers are produced. A few years ago Hon. C. V. Stout, of Parkersburg, in this state, reported to me some interesting facts with reference to the attack of rust and hedges of buckthorn.

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*Zeitschraft f. Pflanzenk. 4: 130.
†Linn. Sept. Nat. 2: 1462.

Quite a number of farmers of Grundy county in the early days planted hedges of buckthorn around their farms. Mr. Stout had observed for a number of years that oats are very badly rusted in the vicinity of these hedges, so that he had learned not to plant any oats in the immediate neighborhood. Away from these hedges rust was not so severe. For the farmers of the vicinity the buckthorn hedge and rust was an instructive and valuable lesson.

SIMPLE BARLEY RUST.

Puccinia simplex.—In 1865 Koernicke described, under the name of *Puccinia straminis* var. *simplex*, the rust upon barley. This rust appears to be quite common in Scandinavia, Belgium, Hungary and Austria, Æcidium unknown. The uredo spores occur in small sori which are longer than wide. These occur scatteringly upon the upper surface of the leaf. The lemon-colored spores round or short elliptical, spiny, yellow, 19 to 20^{u} in diameter or 22–27^{u} x 15–19^{u}.

RUSTS OF OTHER GRASSES.

It will not be necessary to discuss at any length all of the rusts which are common on grasess and cereals, since they have in part been treated in a former discussion; suffice it to say that a so-called *Puccinia graminis* occurs on blue grass, but it is not common nor destructive in this state. The same species occurs on orchard grass. *Puccinia graminis* is, however, extremely common on bent grass (*Agrostis alba*) and several of the related species. *Puccinia graminis*, or a closely related species, the *Puccinia agropyri*, is very common on the following species of the genus: *Agropyron repens*, *A. spicatum*, *A. caninum* and *A. tenerum*. Until it has been determined whether this form is distinct in America it will be better to treat it with common grass rust, which it resembles in a great many respects, and Carleton has shown by inoculation experiments that *P. graminis* occurs on several species of *Agropyron*.

Pucinnia coronata.—So far as the writer knows, this species is common only upon the orchard grass in the state of Iowa, and this is the form which has been referred to *P. coronata dactylidis*. In Europe, however, this rust is common on other grasses.

Timothy rust (*Puccinia phlei pratensis*).—Timothy, so far as the writer knows, is not affected with any rust in the state of

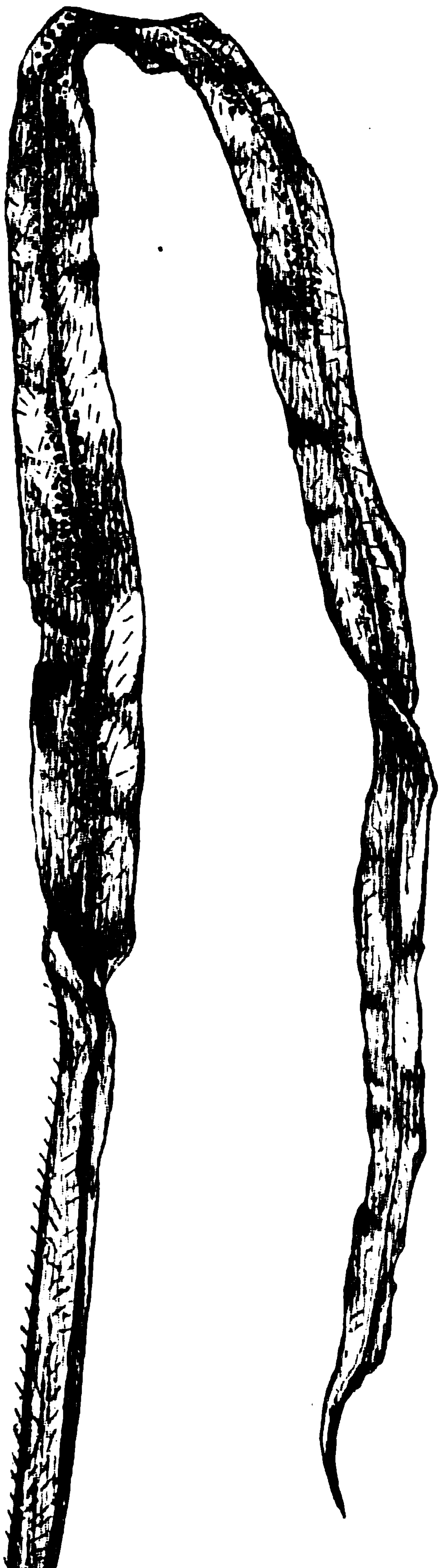
Iowa. In Europe, Eriksson and Henning* have described the above species.

Puccinia graminis has also been reported on timothy in this country. It is possible, however, that the *Puccinia graminis* recorded may be the *Puccinia phlei pratense*. Æcidium unknown; uredo sori perennial occur on the leaves and sheaths; confluent, brownish yellow, 18–27 x15–19 u. The elongated confluent, brownish-black or black sori are open or exposed, or with partially removed epidermis; contain the teleuto spores, which are spindle or club-shaped, somewhat constricted in the middle; chestnut brown, round or pointed; the apex strongly thickened, 38–52u x 14–16u. From experiments made by the Swedish workers it appears that this rust is in no way connected with the barberry cluster cup fungus.

Gama grass rust (*Puccinia vexans*, Farlow.)—This rust is extremely common on *Bouteloua racemosa*. First described by Professor Peck† from specimens collected by Brandegee under the name of *Uromyces brandegei* (Peck). But the species was first correctly determined as a *Puccinia* by Farlow.‡ He determined that there were two kinds of thick-walled spores with a permanent pedicel; the two-celled being far more common in the summer, while the one-celled produced during the fall. The æcidium stage of this fungus is unknown. Uredo sori are produced on the upper surface of the leaf and occur in small yellow spots. Spores oblong or elliptical, minutely roughened, 15–25u across sori, with numerous paraphyses. The one-celled mesospores are globose to oblong. The exospore covered with small papillæ; spores 25–30u broad by 30–38u long. Apex of the spores strongly thickened. Pedicels colorless, longer than the spores; two-celled spores smooth.

Blue stem rust.—Blue stem rust is rather common on tall blue stem (*Andropogon provincialis*) as well as the little blue stem (*Andropogon scoparius*); furthermore, it is common on other species of the genus in southern United States. This species was first described by Schweinitz.§ Uredo sori brownish orange on the under surface of the leaf, sometimes confluent. Uredo spores sub-globose, 21–31u in diameter, roughened.

*Die getreideroste. 153.
†Bot. Gaz. 4: 127.
Saccardo. Syll. Fung. 7: 733.
‡Ellis. North Am. Fungi. *1051.*
§North American Fungi. 295. *2911.*



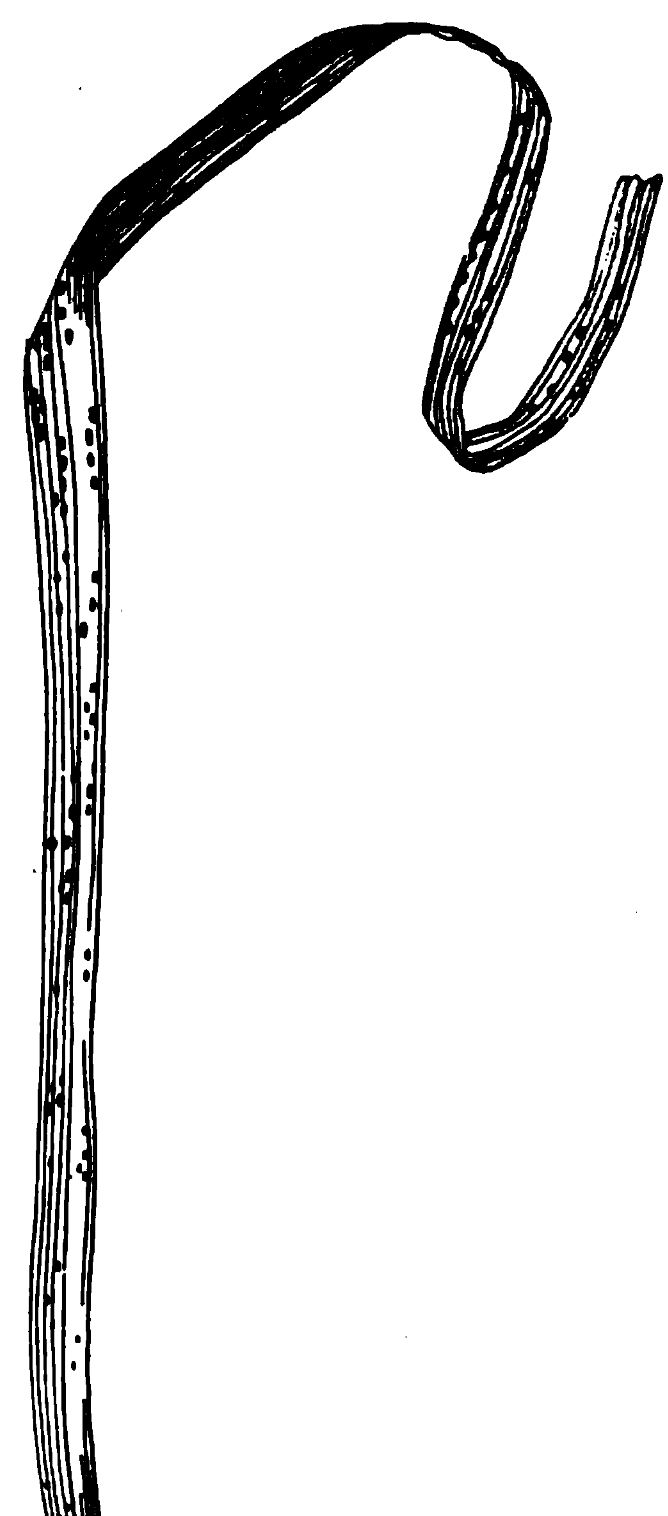


Fig. 129. Uredo Sori of Tickle Grass Rust (*Puccinia emaculata*).
Fig. 130. Teleuto sori of *Puccinia andropogonis* on *A. provincialis*.

Teleuto sori usually on the under surface of the leaves; sometimes on both surfaces, singly or in groups, confluent, the edges of the epidermis of the edges of the sori straight. Teleuto spores two-celled, obovate to elliptical, constricted at the middle. Apex rounded and somewhat obtuse. Spores 30–45 x 15–22^{u}. Pedicels as long or longer than the spores. This species is most troublesome in this state on *Andropogon scoparius*. In some cases over large areas a large number of leaves have been infested with the fungus. It is especially manifest during the month of September and October, uredo spores being most abundant during the month of August.

Switch grass rust (*Puccinia eamulata* Schweinitz).—This species was described by Schweinitz* and occurs upon several different genera, notably *Tricuspis seslirioides*, *Panicum virgatum*, *P. capillare* and *Eragrostis pectinacea*.

Sori numerous, usually on the upper and lower surfaces of the leaf. They are most abundant on the lower. The uredo sori, brownish, elongated, frequently confluent, irregular. Spores sub-globose, 15-20^{u} in diameter, echinulate. Teleuto sori irregular, elongated, frequently confluent, black. The epidermis broken, forming a rim around the edge, lacerated. Spores constricted in the middle. Apex obtuse or acute, 30–48^{u} by 15-21^{u}. Pedicels long or longer than the spores.

Puccinia poarum, Nielsen,† affects *Poa annua*. The pustules or sori of the uredo stage are orange-colored, round to elliptical, provided with sterile threads known as paraphyses. The uredo spores usually have six germ pores. The spores are round or somewhat elongated and spiny. The teleuto sori are black or dark brown, oblong to linear, without sterile threads, long remain covered by the epidermis, the spores are usually two-celled, brownish-yellow to dark brown, provided with short persistent pedicels.

Puccinia anthoxanthi occurs upon the *Anthoxanthum odoratum*. The spores of this species are extremely variable. Ordinarily they are much longer than broad, and with a rather stout, persistent pedicel. The uredo spores are minutely roughened. The *Puccinia phragmitis* is quite common on *Phragmites communis*. The æcidium of this fungus occurs upon a species of Rumex. A second Puccinia has been recognized upon Phragmitis, *e. g.*, *Puccinia magnusiana* Koern. The æcidium of this occurs upon

*Saccardo. Syll. Fung. 7: 663. Burrill. Parasitic Fungi of Illinois. 201.
†Saccardo Syll. Fung. 7: 625. Nielsen. Bot. Tids. III, 2: 26.

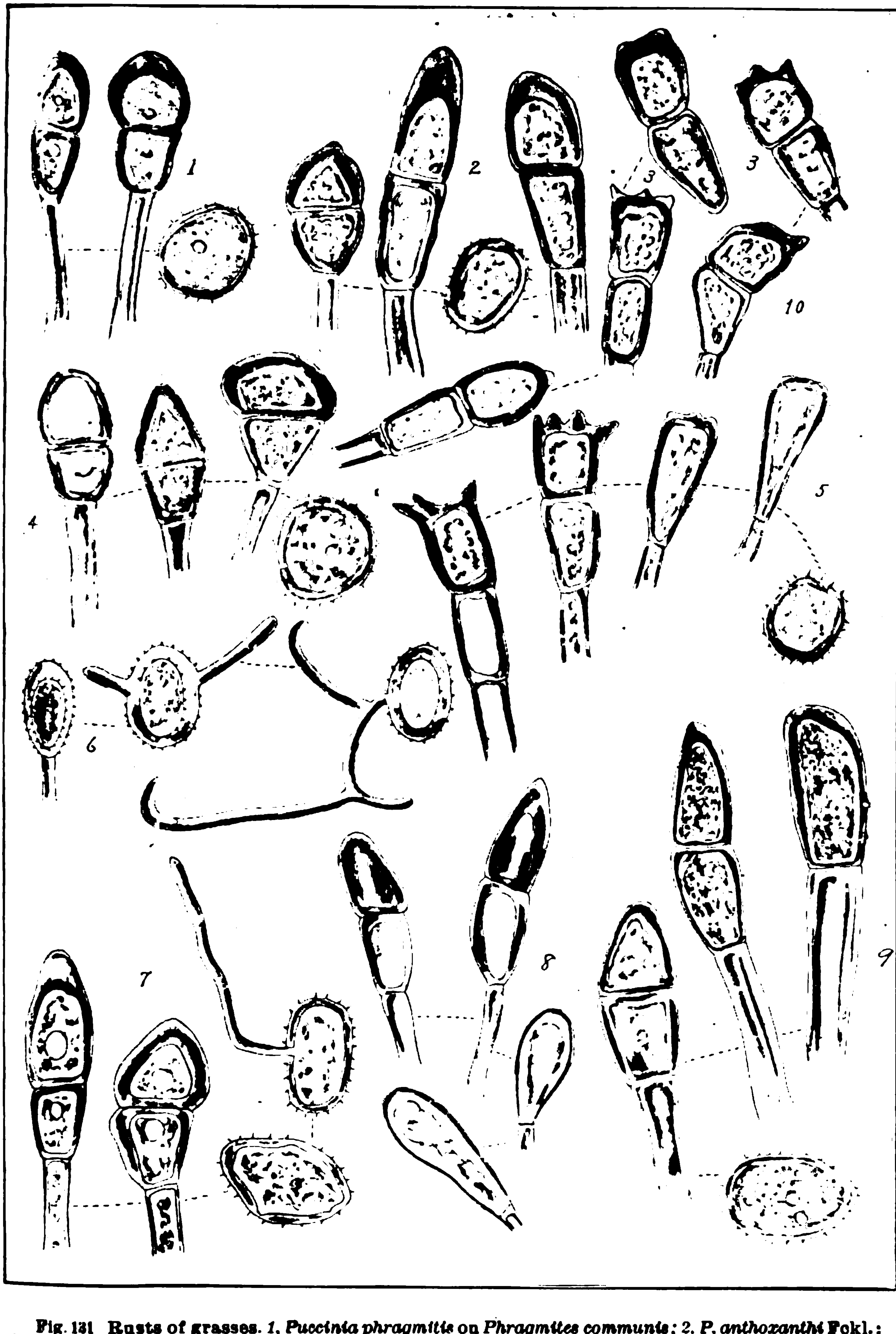


Fig. 131 Rusts of grasses. 1, *Puccinia phragmitis* on *Phragmites communis*; 2. *P. anthoxanthi* Fckl.; 3, *P. coronata* on Calamagrostis; 4, *P. tricuspis*; 5. *P. coronata* on oat leaf; 6, uredo spores of *P. phlei-pratensis* on Phleum, Ericksson and Henning; 7, *Puccinia graminis* on oats; 8, *P. arundinacea* on *Phragmites communis*; 9, on *Spartina cynosuroides*; 10 *P. coronata* on *Cinna arundinacea*. (Pammel and King.)

Ranunculus. Dr. J. C. Arthur, of Lafayette, Ind., has recently determined that the *Æcidium Fraxinii* has its teuleto sporic stage upon Phragmites and that this rust is connected with *Puccinia phragmitis*, and that *Puccinia arundinacea* occurs upon *Phragmites communis* also.

Uromyces dactylidis occurs upon Poa, Dactylis, Avena and Brachypodium. *Uromyces graminicola* occurs upon *Panicum virgatum* and several other grasses. *Uromyces acuminatus*, first described by Arthur, is very common at times on *Spartina cynosuroides*. It received its specific name from the peculiar character of the apex of the spore.

The prevention of rust.—Various opinions have been expressed in regard to the causes of rust and its prevention. By many agriculturists, for instance, it is thought that rust is dependent upon the manner and method of sowing the grain. Some agricultural writers, especially in Germany, have conducted experiments to determine these facts and the statement has been made by some of these writers that where the grain was sown too thick, and soil fertilized, the culms were developed so abundantly that the cereals rust more severely. McAlpine* stated at a conference at Sidney in 1891, that most of the agriculturists of Victoria found that rusts were most severe where the grain had been thickly seeded. Eriksson and Henning† in their treatment of this question states that it appears to have been but a small factor in the determination of rust. Another question discussed along this line by these writers is the question of shallow and deep planting. According to Rostrup wheat sown more than five inches deep is severely affected. The third question discussed is that of sowing by the hand as compared with sowing with a machine. From the results obtained it appears that grain sown by a machine produces a more uniform stand and it was less rusted than the hand sown. The fourth question is that of sowing a mixture of different cereals. This question was early discussed by Sinclair. As a matter of fact it makes very little difference if the cereals are sown separately or conjointly so far as rusts are concerned. The question of climatic influences is an important one as has been shown by numerous investigators. The question, both from an historical and from an experimental standpoint has been dis-

*Rust in wheat. Rep. Proc. of the Conference. Sidney. June 3-8. 1891. Agrl. Gaz. New South Wales. 2: 7. 1891.

†On the diseases of wheat. See Eriksson and Henning. Getreideroste 300.

cussed at considerable length by Eriksson and Henning under the following heads: Heavy rains; sudden temperature changes; wind and dew.

The writers commenting on the subject concluded that the development of black rust is highly favored by the large amount of rain through July and early August. This favors a rapid germination of the uredo spores. The most favorable conditions for the rapid development of yellow rust for winter wheat occurs in the month of April when there is a large precipitation.

Eriksson and Henning have also made some experiments on spraying to prevent rust. They tried such substances as sulphate copper, eauceleste, Bordeaux mixture, chloride of iron and sulphate of iron. It appears from these experiments that spraying with Bordeaux mixture and eauceleste, somewhat lessens the attacks of rust.

Experiments made by Galloway* with fungicides, in which seed, soil and plants were treated, showed that certain fungicides, *e. g.*, Bordeaux mixture, potassium bichromate and some others, were effective in checking rust to some degree, yet the expense and method of treatment render it quite impossible to spray the plants to prevent rust. The experiments by Kellerman, Swingle† and the writer‡ also show that it is out of the question to treat rusts.

Eriksson and Henning, in the work quoted before, recommend only to grow such varieties as are most resistant to this disease. They state that this degree of resistance shows itself to best advantage in years when there is considerable rust. They recommend further that winter wheat be sown early in the fall. In regard to oats, they recommend that the soil should not be heavily fertilized; seed should be sown early in the spring, that all barberry bushes and mahonia be removed, and that weeds which harbor rust, like quack grass, should be removed.

Carleton§ states there is as yet no preventive for wheat rust, at least so far as combating it directly.

Bacterial Diseases.

The known diseases produced by bacteria are constantly increasing. Hartig‖ in his well known work on plant diseases

*Rep. U. S. Dept of Agrl. 1892: 216. Jour. Myc. 7: 95.
†Bull. Kansas Agrl. Exp. Sta. 23.
‡Bull. Iowa Agrl. Exp. Sta. 16: 24.
§Improvements in Wheat Culture. Yearbook U. S. Dept. Agrl. 1896: 497.
‖Lerhbuch. d. Baumkrankheiten. 27. 1882.

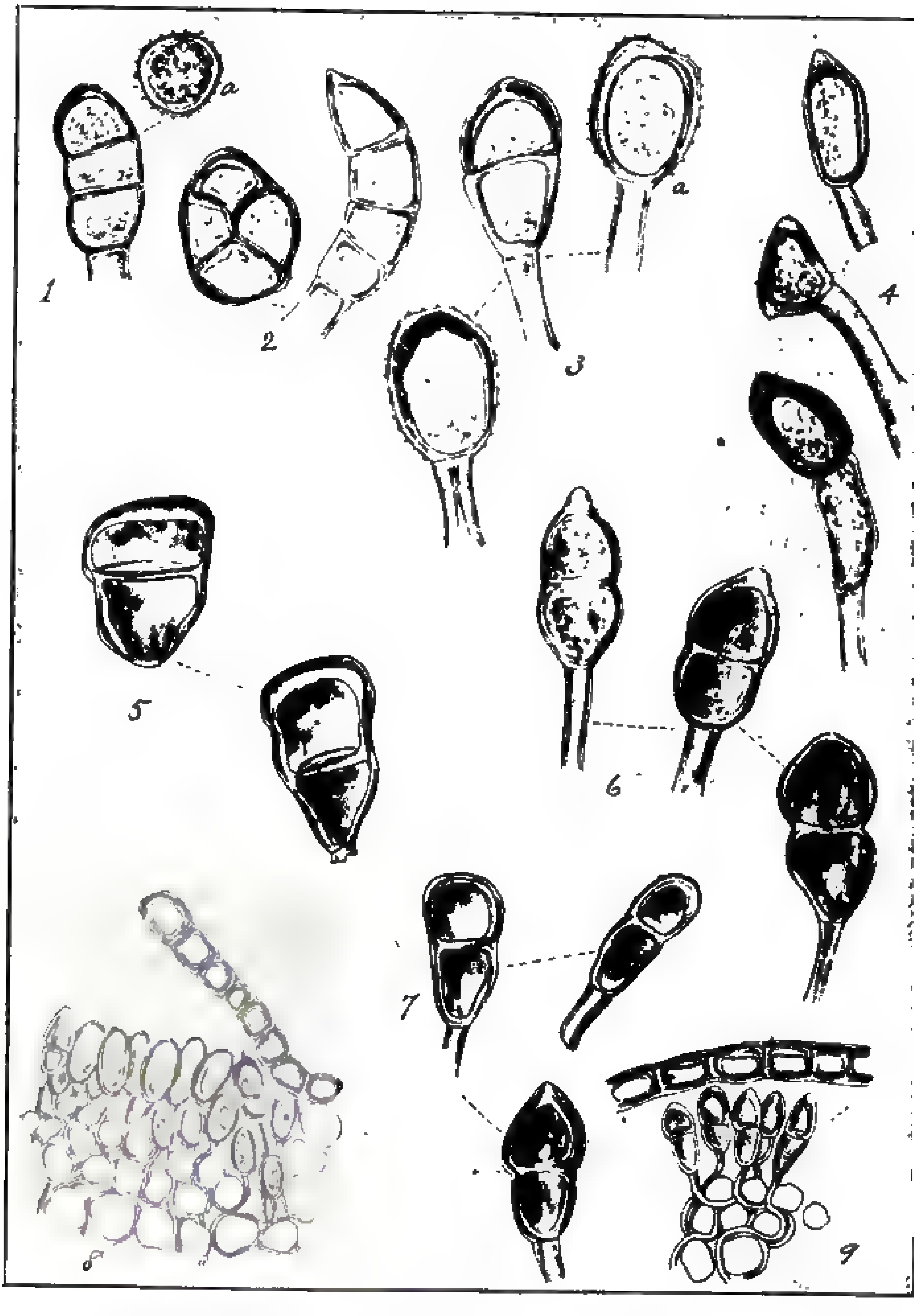


Fig. 133. Rusts of grasses. *1*, a three-celled teleuto spore; *2*, several celled teleuto spore of *Puccinia tomipara;* *4*, *P. veraus*, middle figure a single paraphysis; *9*, *Puccinia graminis*, with mycelium; *8*, *P. rubigo-vera.*

made the positive declaration that bacteria do not produce diseases of plants.

De Bary undoubtedly was one of the most critical and careful of the German botanists. He says:

"Parasitic bacteria do not often appear, according to our present experience, as the contagia of diseases in plants." When De Bary wrote, the following diseases of plants had been demonstrated as due to bacteria: Pear and apple blight,* yellow disease of hyacinth plants;† a disease of wheat, destroying the grain, producing a rose-red color; was supposed, also, by Prillieux‡ to be due to a micro-organism, which destroys the starch grains. Reinke and Berthold‖ also described a wet-rot in potatoes. Later experiments of Van Tiegham§ confirm the results of Reinke and Berthold, that *Clostridium butyricum* (*Bacillus amylobacter*), caused a wet-rot in potatoes.

More recently the list of diseases has been considerably extended. Black rot of cabbage and rutabaga, melon wilt, bacterial disease of rutabaga, tuberculosis of the olive, sorghum blight, bacterial disease of oats, corn wilt, bacteriosis of tomato, egg plant and Irish potatoes, cane disease, gumming of cane and others are caused by bacteria.¶

The literature of the whole subject has been critically reviewed by Dr. Erwin F. Smith.**

In regard to forage plants we are concerned with few of these diseases, namely, bacterial diseases of corn, corn wilt, sorghum blight and bacterial disease of oats.

BACTERIOSIS OF CORN.

In 1889 Burrill†† described a new bacterial disease of corn known as "corn blight," and later published an account in one

*Burrill. Anthrax of fruit trees or the so-called fire-blight of pear trees, and twig-blight of apple trees. Proc. of Am. Ass., Adv. of Sci. 1880: Bacteria as a cause of disease in plants. American Naturalist, July, 1881.

Arthur. Pear blight. Annual Report New York Agricultural Experiment Station 1884: 357. 1885: 241. 1887: 275-288. Bibliography. 300. Am, Nat. 1885: 1181,

History and biology of pear blight. Proc. Phil. Acad. of Nat. Sci. 1886: 322-341. Separate.

†Wakker, J. H. Onderzoek d. Ziekten van Hyacinthen, Harlem. Bot. Centralblatt. 14: 315.

‡Corrosion de grains de ble. etc., par les Bacteriees. Bull. Soc. Bot. de France. 26: 31, 167. 1870.

§Die Zersetzung d. Kartoffel durch Pilze. Berlin. 1879.

‖Developpement de l' Amylobacter dans les plantes al' Petat de vie normal. Bull. Soc. Bot. de France. 36. 283,

¶Erwin F. Smith. Bull. Div. of Vegetable Pathology. U. S. Dept. Agrl. 12.

**American Naturalist. 1896: 626, 716, 796, 912. 1897: 34, 123.

††A bacterial disease of Indian corn. Proc. Soc. Prom. Agrl. Sci. 10: 19. 1889. Bull. Ill. Agrl. Exp. Sta. Aug, 6: 1889.

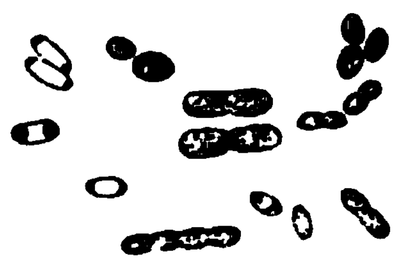


Fig. 133. Bacterial Disease of Corn (*Bacillus cloaceæ*). Burrill.

of the bulletins of the Illinois Agricultural Experiment Station. Wide interest was attached to these investgations, since Billings,* of Nebraska, stated that bacteriosis of corn was identical with the corn stalk disease. His peculiar method of reasoning convinced him that the organism isolated by him was identical with the Burrill organism. This is well stated by Moore.†

"The most interesting part of his investigations was the supposed discovery of the identity of the bacillus which he found in the animal tissues with the one described by Burrill as the cause of a disease in cornstalks. This hypothesis is supported by the fact that by feeding the diseased stalks to a rabbit he produced a fatal disease, and from organs of the dead rabbit he obtained pure cultures of the bacillus. He sent a culture of this bacillus to Burrill, who stated that the organism which he (Billings) had obtained from the organs of dead cattle appeared to be identical with the bacillus which produced the disease on the cornstalks. The correspondence between these two investigators, published by Billings, shows that Burrill was conservative on this question, pointing out obvious resemblances only. The responsibility of the statement that the two bacilli are identical rests with Billings."

Ludwig‡ in his general work on the cryptogams refers to the organism as *Bacillus secalis*, Burrill. Ludwig apparently first applied this name. Russell used the same name.

Moore§ and Smith, who did some very careful work, identified this organism as *Bacillus cloaceæ*, which Jordan‖ found in sewage, and is widely distributed in surface soil.

Characters of the disease.—The first indication of the disease is the dwarfed condition of the young plants occurring in spots of various sizes; soil upon which it occurs is variable, though it usually occurs in the richest soil. In many cases it occurs upon the lowest ground. In one field Professor Burrill observed the following conditions: "The season (of 1887)

*Original Investigations of Cattle Diseases of Nebraska. 1886-1889. Article II. The corn stalk disease in cattle. 163.

†Corn stalk disease. Bull. U. S. Dept. of Agrl. Bureau of Animal Indistry. 13.

‡Die Neideren Kryptogamen. 95. Abst. Warlich Central Bakt. u Parasiten. 70.

§Moore, A. An inquiry into the alleged relation existing between the Burrill disease of corn and the so-called cornstalk disease of cattle. Agrl. Sci. 7: 368.

‖Jordan, E. O. Experimental investigations by the State Board of Health of Mass. 1890: 2. 8. 36.

was quite dry, and there was at no time subsequent to the planting any superfluous water in the area described. The seed germinated and the young corn grew satisfactorily until after the second plowing, when the plants were more than six inches high; then the newly-tilled spot showed, by the change in the appearance of the corn, in a very definite manner, to the very furrow on the margins, a distinct difference from the rest of the field. The corn ceased growing, became yellow and unusually slender, then for the most part died." After corn has tasseled the disease may be found widely scattered throughout the field, affecting a stalk here and there. The young plants usually show a yellowish cast; the roots are also affected; a stalk split lengthwise shows that the inner middle portion of the stem is of a dark color; on the surface of the leaf and stem brownish, corroded spots may be seen—in some cases these spots are covered with semi-transparent gelatinous material; the ears and husks are affected occasionally.

Moore states that he had no difficulty in obtaining nearly pure cultures of this organism from the first stage of the disease. The dwarfed corn resulting from the attacks of bacteria are quite rare. Moore confirms the results of Burrill that this organism occurs in a large number of cornstalks and is abundant in the gelatinous flakes. Burrill's experiments in showing its pathogenic nature were not successful, but later an application of a pure culture applied to the inside of the leaf sheath, without puncture, gave positive results.

Moore says: "Whether these organisms are of themselves able to gain entrance into the parenchy-matous tissue of the leaf sheaths after being lodged by various agencies against the exterior of the plant, or whether they are inoculated into the tissues by means of insects or injuries to the epidermis otherwise inflicted is not determined."

This organism is therefore parasitic, and should be classed with the faculative parasites. It has been shown that in addition to *Bacillus cloaceae* other saprophytic organisms occur, and that these may produce lesions. This is not inconsistent with the work done by Russell,* who has shown that a large number of bacteria, mostly saprophytes, can live for a certain period and spread as parasites.

*Bacteria in their relation to vegetable tissue. Rep. Johns Hopkins Univ. Hospital 3: 223. 1893.

This organism is described by Moore*as follows:

Morphology.—A motile bacillus varying in length from 1.3 to 2^{n}, ends rounded. Appears in cultures singly or united in short chains or clumps. From five to fourteen flagella have been demonstrated. It stains readily with aniline dyes.

Cultural characters.—It develops a grayish, somewhat vigorous, glistening, non-viscid growth on the surface of agar. In the depth of agar it is more feeble. Gelatin is softened along the needle track and beneath the quite vigorous grayish growth which appears on the surface at the end of six days. It liquefies very slowly. The liquid gelatin is clear, with a viscid grayish sediment and strongly alkaline in reaction. On potato a dull grayish, non-viscid growth appears within twenty-four hours. In alkaline bouillon the multiplication is quite active, the liquid becoming heavily clouded in twenty-four hours. The casein of milk is coagulated in about eighteen days. It possesses active fermentative properties. In the fermentation tube, when filled with bouillon containing 2 per cent dextrose, the closed bulb is filled with gas in forty eight hours. The liquid is very acid in reaction. The gas consists of 72 per cent CO_2 and 28 per cent H. In a similar tube containing saccharose the fermentation is quite as active, but the proportion of the gas constituents is different, being 66 per cent CO_2 and 34 per cent H. In bouillon containing lactose the closed bulb of the tube is not filled with gas until the fourth day. The gas is practically the same as that produced in the saccharine bouillon.

Burrill supposed the organism to be widely distributed. Moore also observed the disease in Maryland and Indiana, and some of the organism has been isolated here at Ames. The general characters certainly correspond, and diseased material submitted to Burrill had his verification. Cultures made by one of us and compared with his indicated its presence here. The dwarfed condition mentioned by Burrill was especially pronounced in one field of corn grown in bottom land. This field has since been planted with mangolds, turnips, alfalfa, and beans, besides receiving a heavy coating of various fertilizing material. In year 1897 it had an exceptionally fine crop of corn. It may be that this root trouble is due to an entirely different cause, as has been suggested by Moore.

*l. c. p. 46.

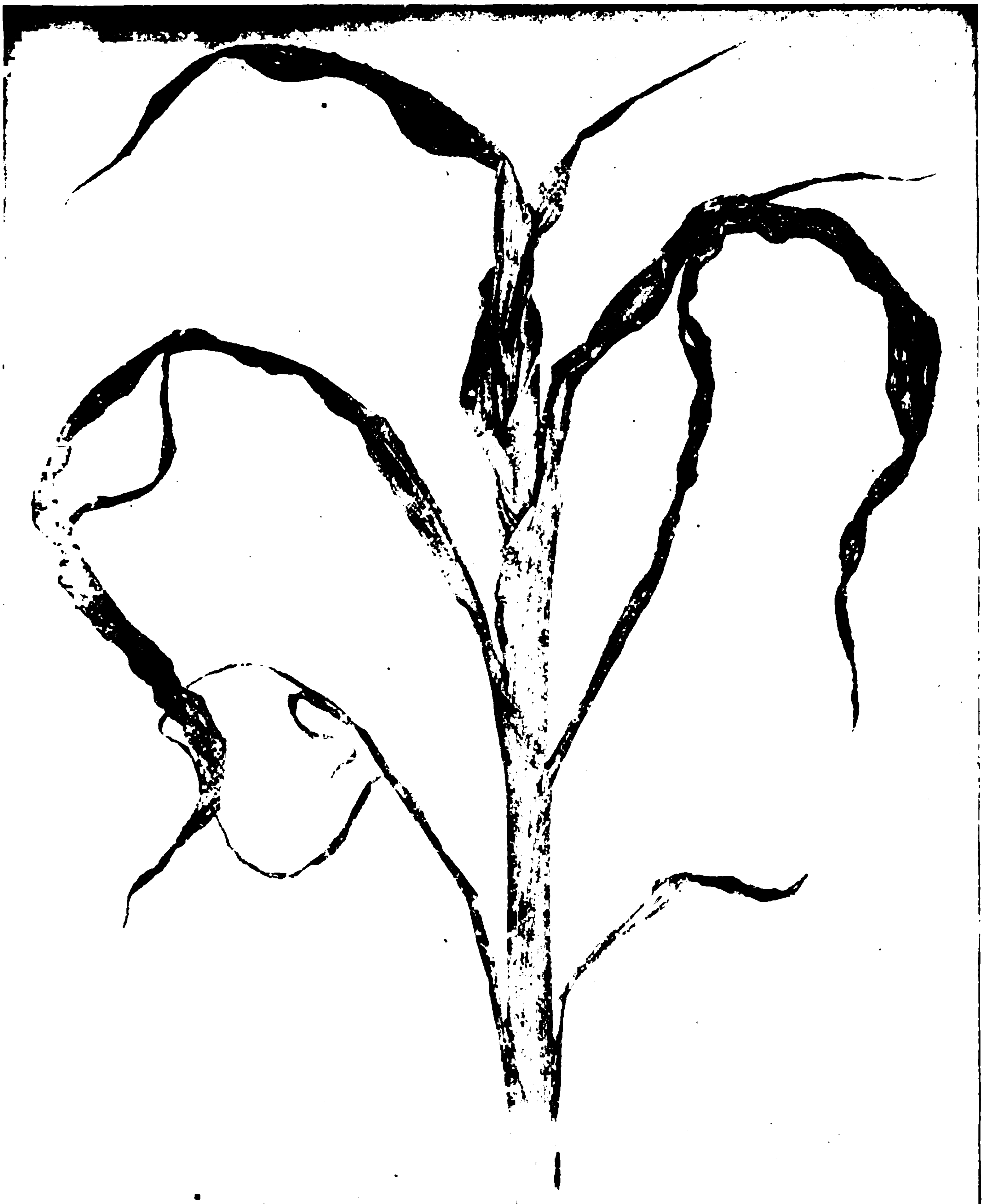


Fig. 134. □ Plant affected with corn wilt. (Stewart. Geneva, N. Y., Agrl. Exp. Sta.)

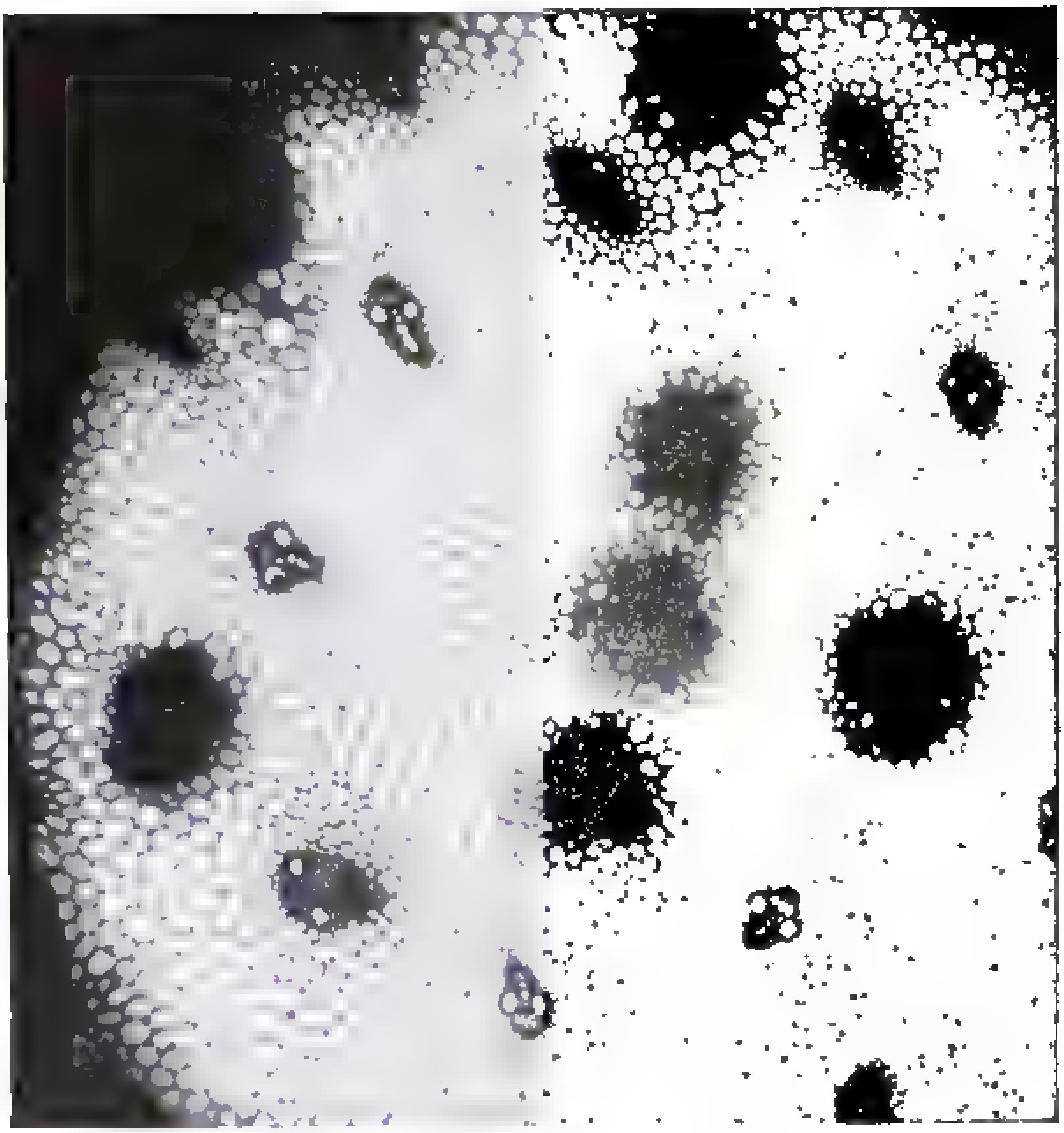


Fig. 135. Corn wilt. Cross-section stem of maize, the black areas, the vessels filled with bacteria. (Stewart, Geneva, N. Y., Agrl. Exp. Sta.)

CORN WILT.

Another bacterial disease of corn has recently been worked over quite carefully by F. C. Stewart* of the Geneva, New York Agricultural Experiment Station, and there is hardly any room to doubt that this disease is different from the Burrill disease and is due to a specific cause.

Stewart briefly called attention to a disease occurring on Long Island which had the following characters: The plants wilt and dry up, although the leaves do not roll as they do when they die from lack of moisture. In young plants death occurs in a few days. In older plants it requires a longer time for the disease to run its course. The disease may attack the

*Garden and Forest. 10: 3. 8.

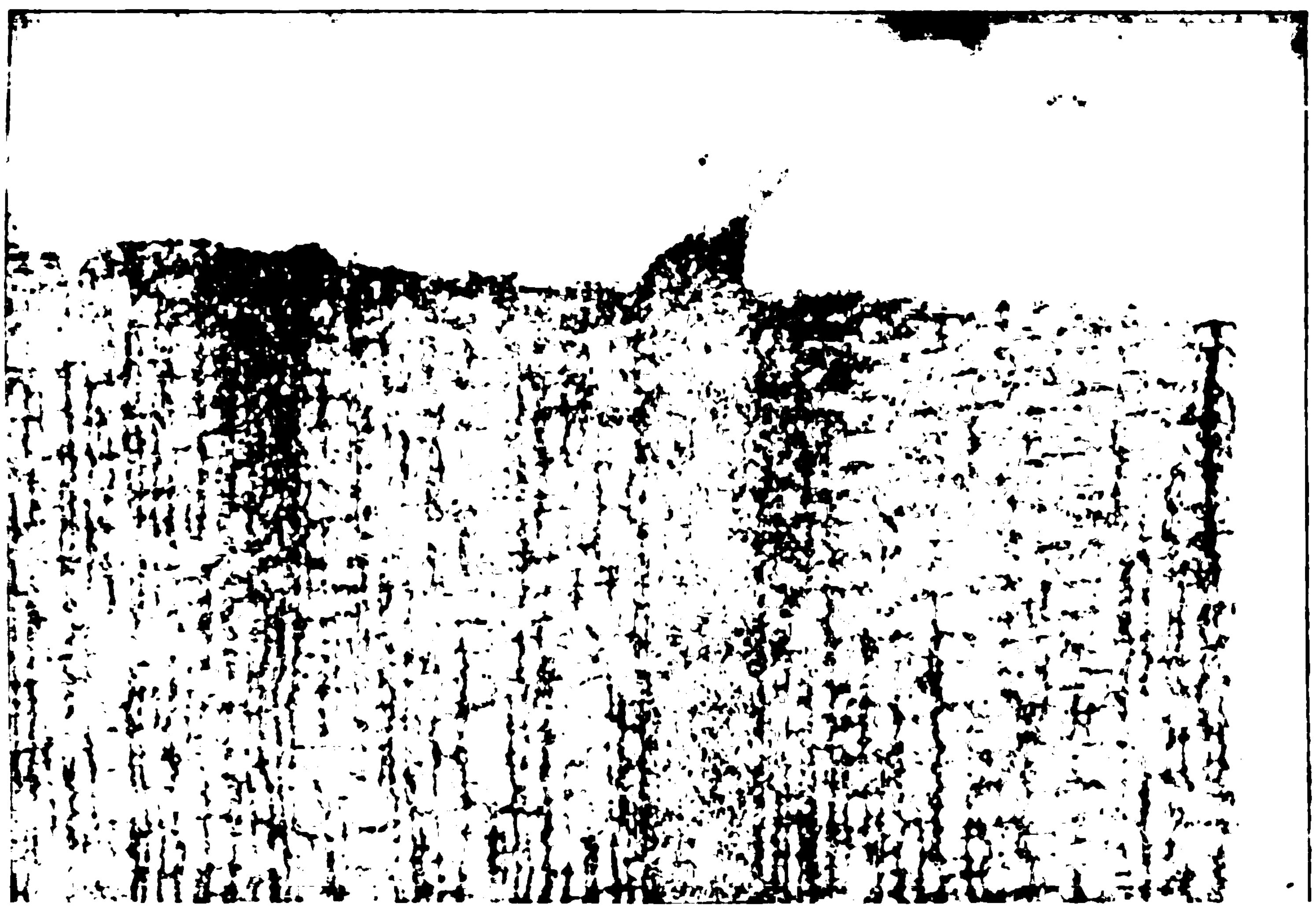


Fig. 136. Corn wilt. Longitudinal section of maize stem showing a mass of bacteria in the large ducts. (Stewart, Geneva, N. Y., Agrl. Exp. Sta.)

plant at any stage of growth, but is most injurious when the ears are forming. The disease is scattered through the field, diseased plants frequently occurring in the same hill with healthy ones. It is also found on various kinds of soil, but it seems to prefer the early dwarf varieties of corn, like the Manhattan. Stewart further states that certain varieties are more severely affected than others. It was first observed at Queens, N. Y., where it has been known for three years. Occasionally an entire crop has been ruined and a loss of from 20 to 40 per cent has been frequent. This disease seems to only affect the sweet corn. Field corn and pop corn are entirely exempt.

Stewart* thinks the organism is not only disseminated by the seed, but may also be spread by manure and implements. To prevent this disease use care in selecting the seed. Plant resistant varieties.

Quite recently Dr. Erwin F. Smith† has investigated this disease and named the organism *Pseudomonas Stewartii*.

SORGHUM BLIGHT.

Related to the diseases above is what is known as sorghum blight (*Bacillus sorghi* Burrill.)

Burrill‡ first described sorghum blight, and the organism which causes the disease. Kellerman and Swingle† have

*Bull. N. Y. Agrl. Exp. Sta. Geneva. 130: 423.

†Proc. Am. Ass. Adv. Sci. 47: 422. 1898.

‡Burrill. A disease of broom-corn and sorghum. Proc. Soc. Promotion of Agrl. Sci. 8: 30. The Microscope, 7: No. 11. 1887.

extended Burrill's work so that we are now pretty familiar with the nature of the disease.

The red blotches on the leaves and sheaths are familiar objects to almost every one who has observed sorghum. On the inside of the sheath the color is somewhat intensified, being of a brilliant carmine color. The red blotches are in the early stages somewhat circumscribed, but later they are large and irregular, often elongated. The roots are often affected, more especially in young plants. The disease makes its appearance quite early. On the college farm many young plants from four to six inches high showed yellow blotches extending across the leaf; sometimes three or four appeared on leaf; a little later a small purple blotch appeared in the center of the colorless portion. Burrill, in describing the disease, says: "Sometimes the appearance of injury is noticeable upon young plants. They grow very slowly, are slender and yellowish in color, and are easily pulled from the ground. The lower leaves die, having previously shown discolored (yellow or red, mostly the latter) patches on various parts of their surface. Not unfrequently these conditions prevail in special areas of the field; perhaps several acres, not apparently different in composition, condition of drainage, etc., will have, throughout their extent, this dwarfed and sickly crop, while the rest of the plantation is healthy and vigorous. More often the evidence of disease appears, to a greater or less extent, over the entire field, all or an exceedingly variable proportion of the plant suffering; not unfrequently stalks four or five feet high can be lifted with ease from the soil."

The *Bacillis sorghi* when growing on potato is said to produce a pearly white growth, although there is sometimes a slight tinge of yellow or pink. In old cultures it is said to be of a dirty white and much wrinkled. On agar the growth is very much the same, the margin is usually crenate. In cultures obtained by the writer the growth was dirty yellow; this kind of growth was not only obtained once but several times. It seems therefore reasonably demonstrated that this organism is the cause of the disease, since a specific micro-organism is constantly associated with the disease and inoculation experiments made with pure cultures derived from the organism found in the discolored patches have shown, beyond a doubt, that the organism produces the disease.

*Kellerman. Preliminary report on sorghum blight. Bull. Kansas Agrl. Exp. Sta. 5: 281. 1888.

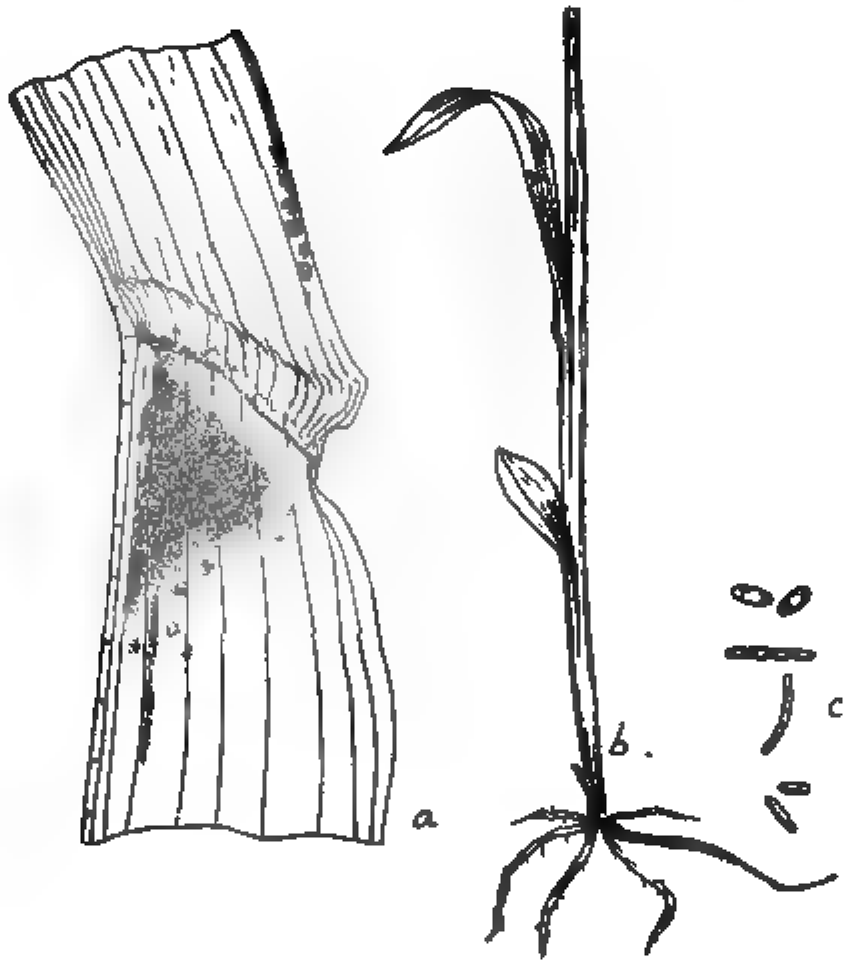


Fig. 127. Sorghum blight (*Bacillus sorghi*); *a*, leaf and sheath affected; *b*, young affected plant; *c*, rod-shaped bacilli. (Kellerman and Swingle.)

Treatment.—Burrill and Kellerman have shown that soil upon which sorghum has been grown contains the organism and that they occur in old stubble. It has also been noted that since sorghum fields are not burned over, the disease is on the increase. It would certainly seem advisable to burn over old fields But this will not prove sufficient, since the fungus occurs in the soil. Many fungus and insect enemies can be checked very materially by rotation of crops. In either case we cannot expect to remove the disease entirely, since it occurs where sorghum has never been grown. It is probable that the micro-organism is carried through the air and water, as well as the soil.

GUMMING OF SUGAR CANE.

In 1893 N. A. Cobb,* New South Wales, gave a full account of the disease in sugar cane which caused a gumming; this he attributed to *Bacillus vascularum.* The disease seems to have been present in Australia for a considerable length of time, the cane planters having been familiar with a disease characterized

*Ag. Gazette. N. S. Wales. 4: 777.

by the exudation of a yellow substance by the cane. It appears that this disease is quite destructive in portions of the island and that it is not spread to any great extent through the air. The disease starts from the seed. The general characters are as follows: Here and there will be seen stools containing one or more stalks with dead tops; the base of the area in such cases will be found to be rotten, usually having one or more cavities of considerable size occuring near the top of the stalk and filled, or partially filled, with offensive matter. A microscopical examination shows that this is not general, but local. This gum is confined to the vessels, which are plugged with it. The gummy substance contains a substance called *vasculin*. The yellow gummy matter never occurred without bacteria. The organism responsible for this disease is a rather short bacillus united in chains, the rod being surrounded by a gummy exudate. The evidence that this organism is the specific cause of this disease is not demonstrated, since the author did not cultivate this organism, but relied wholly on the general facts and his success in inoculating healthy cane from diseased plants by means of an infection needle.

Quite recently W. R. Dodson* has given an account of red cane, expressing the opinion that one or more bacterial forms accompany red cane, and that the disease in question is due to the breaking down of the protoplasm. No definite results were obtained by Dodson. The red coloration is of common occurrence on the cut ends of cane in the standing stalks, as well as those that are used for sugar purposes, and Dodson states it is very common where injury occurs. I have noted its common occurrence on sorghum in this state, and an examination of the cultures of sorghum cane showed that *Saccharomyces glutinus* was common, but not necessarily the whole cause. In some unexplainable way this red coloring matter is produced where caue is injured. We called attention to this under sorghum blight.

Mr. N. A. Cobb† describes the red rot of cane due to an imperfect fungus, so that it is evident that more than one organism must be considered in the reddening of cane.

*Bacteriological Notes on Red Cane, in Wm. C. Stubbs' Sugar Cane. 1: 173.
† Agrl. Gazette. N. S. Wales. 4. 808.

PASTURES AND MEADOWS OF IOWA.

Iowa as a grass state.—The importance of Iowa as an agricultural state rests largely on the production of hay and grass. Sage* states that the hay crop of Iowa for the year 1897 amounted to 5,301,404 tons, valued at $22,305,023. The pasture crop is probably equal to this, or greater. The hay industry, including the grass grown in our pastures, supports a large population.

In the census of Iowa for 1895,† the following totals are given for the production of hay and grass for the state: Timothy, 2.182,791 acres were cut for hay, with a product of 1,726,-920 tons, valued at $11,741,929; Hungarian and millet, 91,167 acres were cut for hay, with a product of 95,095 tons, valued at $499,118; prairie grass, 1,760,159 acres were cut, with a product of 1,266,688 tons, valued at $5,859,449; 2,689,699 acres of corn were cut, valued at $9,262,534; 8,104,330 acres are devoted to pasture, valued at $14,700,792. This makes a total of 14,824,-146 acres devoted to pasture and meadow purposes. The total product has a value of $42,063,822. The value of other grass products is given in another connection. Corn is the only product that exceeds in value that of grass.

The production of cultivated grasses has greatly increased during the last decade. Statistics given in the census report for 1880, by Hon. J. A. T. Hull,‡ show that 3,613,941 tons of hay were produced in the year 1879. At that time an enormous amount of wild hay was shipped to Chicago and other points from northwestern Iowa.

Grasses.—Iowa has long been noted for its excellent pastures and meadows. Before settlement began the greater portion of Iowa was a great meadow, in which most valuable native grasses flourished. The grasses were excellent. It was the ideal land for the herdsman. Hay was cut in abundance every-

*Report Iowa State Agrl. Soc. 1897. 158.

‡W. M. McFarland. Census of Iowa for 1895. 630. 1896. Des Moines.

†Census of Iowa. 1880: 258. 261.

where. As late as 1890 the making of wild hay formed an extensive and leading industry in northwestern Iowa. The chief centers of export hay trade were Bancroft, Algona, Rolfe and other points in northern and northwestern Iowa. Since 1890 many of the large tracts of northern Iowa have been brought under cultivation, and now small grains and corn are largely grown. At one time in northeastern Iowa much of the land was devoted to small grain culture, but the successive failures of this crop caused a radical change in methods of agriculture. Wheat is now the exception. Larger areas are now devoted to the growing of bluegrass and other meadow grasses.

In a paper on the forage conditions of central Iowa, the writer* has said, "West of Ames there are several important valleys—the Des Moines, Coon, and Boyer; northwest of Carroll there are the Little and Big Sioux, the Maple and the Floyd. Along the Coon and Des Moines rivers the country is rough, and but little hay is cut, though much of the timber land is used for pasture. Along the Maple, Boyer and Floyd rivers the immediate banks contain some timber, but the flood plains are open and covered with a luxuriant growth of grasses.

The forage question in central Iowa is very different now from what it was fifteen years ago. At that time considerable areas of unbroken sod still remained. Now the wild prairies have almost ceased to be a factor in the production of hay. The extensive prairies have given way to cultivated fields and pastures. Small unbroken areas occur here and there, but these are confined to the small drainage basins between the hills, and exist largely because in times of considerable precipitation these depressions are too moist for proper cultivation. The Boyer and Maple valleys are noted for the large crops of wild hay annually produced. The same may be said of the rich alluvial flood plain of the Missouri. This plain varies from a few to fifteen miles in width, the average being from eight to twelve. The hay crop constitutes one of the chief sources of revenue for the farmers of this region, and could be made much more important if they would follow a more rational system of cropping.

The chief hay plants cultivated in central Iowa are timothy, redtop, bluegrass and red clover. The principal plants used

*L. H. Pammel: Notes on the grasses and forage plants of Iowa, Nebraska and Colorado. Bull. U. S. Dept. Agrl. Div. of Agros. 9:7.

Fig. 128. Blue grass pasture on College grounds, with College herd.

in pastures are bluegrass, white clover, redtop and timothy. In the Boyer and Maple valleys and on the Missouri bottoms the wild grasses predominate. To a limited extent alfalfa meadows have been started in Carroll, Ida and Woodbury counties. The loess hills, skirting the Missouri bottoms, are mostly cultivated, though unbroken wild meadows and pastures still remain. In the eastern portion of this district considerable corn fodder is used as forage, the amount used depending largely on the condition of the pastures and meadows.

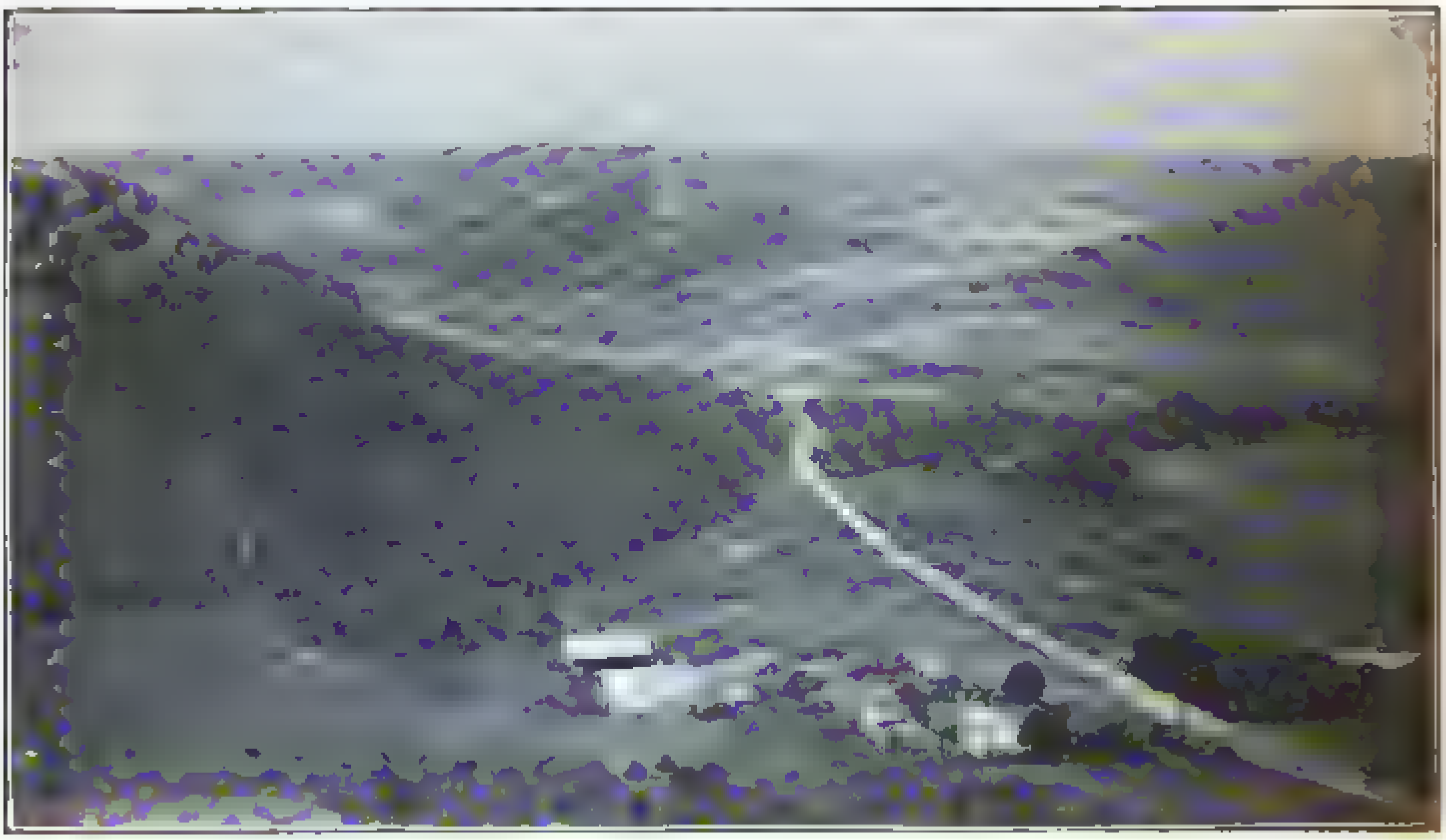


Fig. 189. Grass covered hills and forests along the Mississippi. The open places on hills contain *Andropogon* and *Bouteloua*.

Many other grasses have been tried with varying success. Orchard grass, naturalized in many places, is one of the most successful. Tall oat grass gives some promise. Italian rye grass is unable to resist the cold of our winters and is a complete failure. Meadow foxtail (*Alopecurus pratensis*) does fairly well as an early grass when sown the season before, but is hardly adapted to this section. The most promising of the recently introduced grasses is smooth or Hungarian brome. The short-awned brome has also been tried and is very promising. Rye and barley are often used as forage plants. German millet and Hungarian grass find extensive use in some seasons. Broomcorn millet is frequently sown in northern and northwestern Iowa."

Many native species of grasses occur, and they vary in quantity and quality in different sections of the state. The dominant grasses of central Iowa are big blue stem (*Andropogon provincialis*) and little blue stem (*A. scoparius*). Both of these species are frequently called blue joints. Several species of elymus are also abundant, as wild rye of the prairies and meadows; wild rye (*Elymus robustus*) on the flood plains of streams, and dennet grass along the borders of woods. Other common grasses are: Indian beard grass, or bushy blue stem (*Andropogon nutans*) of prairies and open woods; tall grama grass (*Bouteloua racemosa*) of the dry praries and gravelly knolls; nodding fescue (*Festuca nutans*) in woods; slender fescue (*F. tenella*) in dry, sterile soils; Short's fescue (*F. shortii*) in low prairies, a most valuable species; switch grass (*Panicum virgatum*) in rather moist meadows; satin grasses (*Muhlenbergia racemosa, M. willdenovii* and *M. mexicana*) in moist soil of open woodlands and meadows; swamp chess (*Bromus ciliatus*) in open woodlands; fowl meadow grass (*Poa serotina*) in low grounds along streams; wire grass (*P. compressa*) and squirrel tail grass (*Hordeum jubatum*), an introduced species, in meadows and waste places; blue joint (*Calamagrostis canadensis*), reed canary grass (*Phalaris arundinacea*), common reed grass (*Cinna arundinacea*), and floating manna grass (*Glyceria aquatica*) in marshy places and shallow water; large rush grass and bunch grass in dry prairies. In northeastern and western Iowa the above as well as some additional species occur. Among the latter are western wheat grass (*Agropyron spicatum*), bearded wheat grass (*A. richardsoni*), blue grama (*Bouteloua oligostachyga*), slough grass (*Spartina cynosuroides*) and big sand grass (*Calamovilfa longifolia*).

Leguminosæ.—Members of the Pulse family constitute an important part of Iowa pastures and meadows. Every well regulated farm should have some leguminous forage plants. This large family contains some 7,000 species of plants. Few of these have deleterious properties and many of them are of economic importance to man. Our Iowa species vary from the diminutive clover to the large Kentucky coffee tree. Many hundred species are valuable for forage, but only a few of these are grown in Iowa. All of our leguminous forage plants belong to the sub-order *Papilionaceæ.*

Red Clover (*Trifolium pratense*) is the most important of our forage plants. It is well adapted to every section of the state;

it stands drought well and is not easily winter killed. The winter of 1898 and 1899 was an exceptional year, as it was killed in many sections of the state. Medium clover (*Trifolium medium*) is also frequently cultivated. Clover is not only valuable as a forage plant, but no other leguminous plant is so valuable for this state as a soil renovator. White clover* (*Trifolium repens*) is spontaneous in all parts of the state. It is a native of Europe but has long been naturalized. White clover is abundant in pastures, meadows and along roadsides. It is only valuable as a mixture in blue grass meadows. White clover is richer in protein than red clover and much more so than blue grass. The only objection made against this plant is that it causes profuse salivation when the seed is forming. Alsike clover (*T. hybridum*) is becoming much more common in this state, and has an excellent reputation as a pasture plant. For low meadows it is more valuable than red clover. Crimson clover (*Trifolium incarnatum*) has been tried repeatedly but is not adapted to Iowa conditions. It suffers much from insects, fungus enemies and drought in late summer. Several annual leguminous forage plants are frequently cultivated in this state. The most valuable of these are Soy Bean (*Glycine hispida*) which is not only an excellent drouth resister but produces a large amount of forage. The cow pea (*Vigna catjang*), though long and favorably known in the south as a forage plant, is coming into prominence in this state. Not only does it resist drouth, but it is productive. Experiments made here at Ames indicate its great value for Iowa. The common field pea (*Pisum arvense*) is grown but little. A number of our native leguminous forage plants are valuable. Two naturalized species are common in all parts of the state—yellow sweet clover (*Melilotus officinalis*) and the white (*Melilotus alba*). Though held in esteem in some of the southern states we cannot so regard them in this state because of their weedy character. They are held in esteem in the south because they are excellent soil renovators and beemen consider them valuable because they are excellent honey plants.

The most widely distributed of all the native leguminous plants is Canadian rattle-weed (*Astragalus canadensis*), a thrifty, hardy and vigorous species found in woods, low meadows, and prairies. It is eaten by stock but becomes rather woody when

*For good accounts of clover see Beal. Grasses of N. Am., 1:320 (Ed 2) Wallace Clover Book.

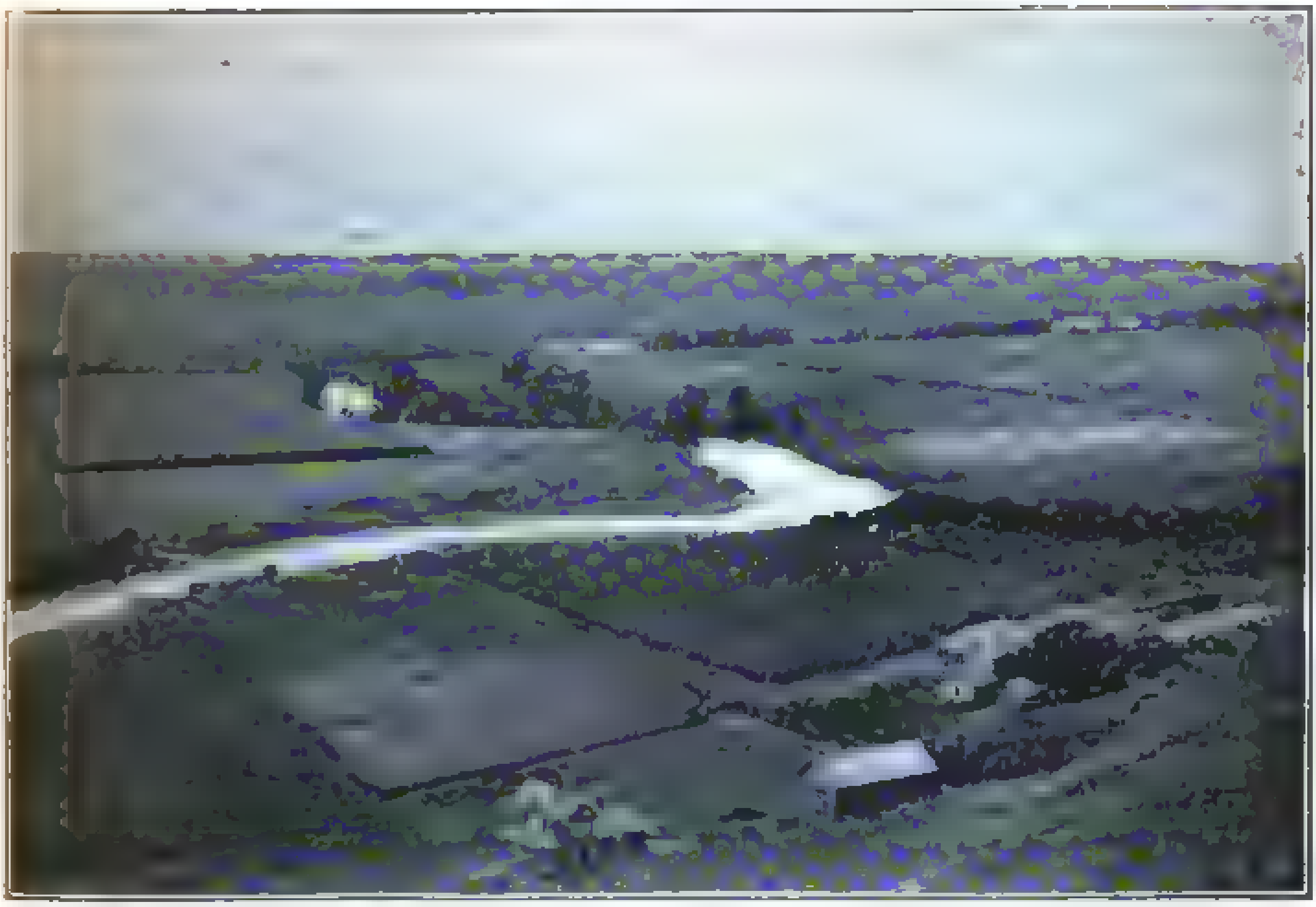


Fig. 140. Alluvial bottoms of the Missouri, covered with coarse grasses. *Spartina cynosuroides*, *Andropogon* and *Phalaris*.

old. Buffalo pea, or ground plum, is common on dry sterile hills throughout the region and affords valuable forage. American vetch is one of the most valuable of the native legumes. It grows in the moist soil of low prairies and open woodlands. This vetch is well adapted to the conditions of western and northwestern Iowa, and does well under cultivation. The prairie clovers (*Petalostemon violaceus* Michx., and *P. candidus* Michx.) are common on the prairie everywhere, as also on the loess soils of western Iowa. These plants are seldom eaten by stock unless forage is scant. *Dalea alopecuroides* Willd. is common throughout the loess region and has been introduced farther eastward. Wild vetch (*Hosackia purshiana*) well-known as a valuable forage plant of the northwest, is indigenous to the loess, though not abundant except locally. It has been introduced into Boone county. Running buffalo clover (*Trifolium stoloniferum* Muhl.), a native, is worthy of a trial under cultivation. Mention should also be made of a loco plant (*Oxytropis lambertii* Pursh.), native to this region. Though often consumed by stock, no complaints have been made that

it produces loco poisoning. Rattlebox (*Crotalaria sagittalis* L.) occurs in the sandy bottoms of the Missouri river. Complaints have frequently been made of the trouble it causes when fed to horses. The disease it produces has been called "crotalism."

Present and future conditions of Iowa pastures.—As has been said before, the native prairie turf is rapidly diminishing in Iowa, and it is no longer a great factor in the production of beef. In a valuable paper on the subject of the forage conditions of the prairie region, Mr. Jared G. Smith* says: "The amount of raw prairie land suitable for farming is rapidly becoming less, and before we have converted all of it into plowed land let us consider whether such a course is most advisable. There is no longer any large tract of unbroken prairie east of the Mississippi river. The prairies are now confined to the Dakotas, southern Minnesota, Iowa, Nebraska, Kansas, Oklahoma, Indian Territory and Texas. In all these states the richest of the prairies have been converted into wheat, corn, or cotton fields, to add their products to the congested condition of the world's markets."

The prairie lands remaining in Iowa make fine hay and afford good pasturage. Many of the species are highly nutritious and valuable in their places. This is especially true of blue joint grass (*Andropogon provincialis*), which covered millions of acres of our broad fields. For many years the practice of breaking up these wild meadows and planting with corn, oats and wheat has been followed, with the result that our markets have frequently been overstocked with these cereals. The phenomenal shortage of the cereal crops in 1897 has stimulated farmers to put more fields into these crops, with the inevitable results to follow—stagnation. The question has been well stated by Jared G. Smith:† "It has been demonstrated, both by experiment and practice, that the farmer who sells beef, pork and mutton that he has produced from the corn and grass raised and fed on the farm, makes more money per acre of his land and per dollar of his capital than the one who grows only wheat or corn or cotton. It is not necessary to entirely discontinue raising these crops, but if we are to produce a surplus to be sold in foreign markets, it is best to export that surplus in the most condensed and marketable form, as meat and animal products, that the people want to

*Yearbook U. S. Dept. Agrl. 1895: 310.
†l. c. 311.

Fig. 141. Woods with wood grasses, like Bromus. Blue grass used for pasture in central Iowa.

buy, rather than in the original crude and bulky state, that the people do not want to buy."

In the long run the farmer will make most money who devotes his fields to the growing of forage crops to feed to dairy cows, furnish beef, making use of all the raw products at home, thereby saving not only much of the cost of transportation, but maintaining the fertility of the soil. By doing so the farmers will maintain their pre-eminence in agricultural lines. The valuable farm lands of Iowa must be changed to something more productive than the growing of cereal crops for export sale. The Iowa farmer, whose land is worth $60 per acre, cannot compete with the Dakota farmer, whose land is worth only $10 to $15, in the growing of wheat. The stock and dairy industries are the avenues which will enable the farmer to succeed. Anything that will enhance the productive capacity of our soils for the production of forage conditions will help the Iowa farmer.

We shall therefore briefly discuss some of the more prominent grasses and the maintenance of pastures. The chief glory of our pastures and meadows resides in the turf, which is constantly being formed. Professor Brewer* says: "It is believed that permanent pastures, if well handled, continue to grow better for fifty years or a hundred years; some say for much longer than that. It is nearly forty years since I was in England, but I well remember that English farmers told me that a pasture or meadow had to be at least twenty-five years old to be good, and was not really excellent until the third or fourth rental (forty-two or sixty-three years) at least. There was no other one feature in English scenery that so impressed me as the English turf, whether seen in either the pastures or the parks and lawns. Many of the parks are in fact pastures. One sees sheep everywhere. Even in the play grounds of the colleges and schools one sees flocks of sheep, kept there for the benefit of the turf. When Connecticut public opinion shall protect sheep on the Yale athletic fields from dogs, then all of Connecticut will be able to grow more of the mutton it consumes and the state will be richer by very many millions of dollars."

"Precisely so with the turf grasses. A single species may exist as numerous varieties, some more robust or aggressive, others less so, having different capacities to withstand too wet

*Rep. Conn. Board of Agrl. 1896: 85.

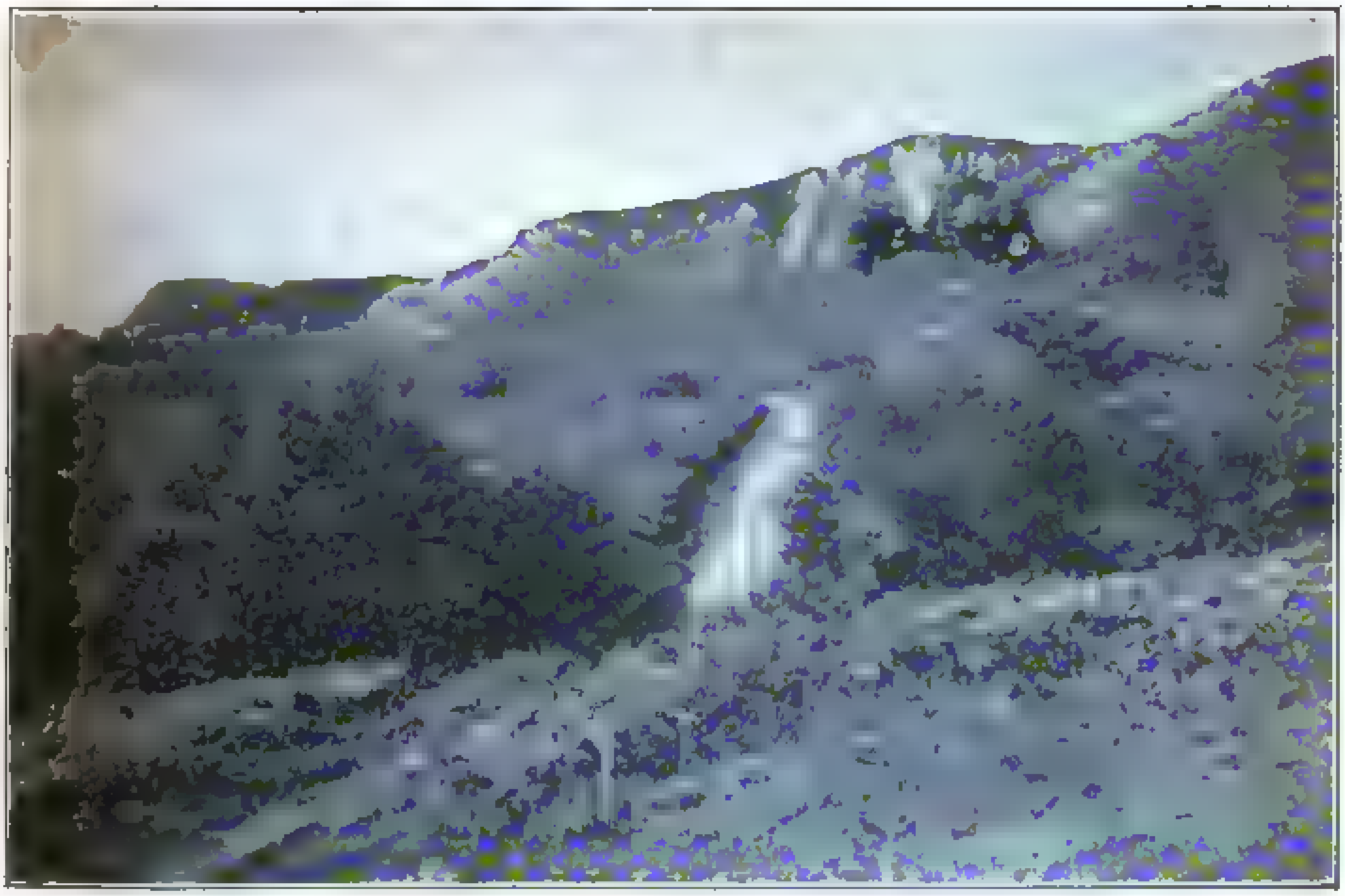


Fig. 142. Loess hills of western Iowa where wheat grass and grama grasses grow.

or too dry periods, to stand drouths or other vicissitudes of climate, or to endure or flourish under the grazing of cattle. Let us keep in mind, also, that while the natural tendency of plants is to produce seeds and propagate in that way in crops of grass, either when cut for hay or grazed for pasture, it is foliage, not seed, that is the aim of the farmer."

Our own native sod of blue stem, untouched for ages, becomes more valuable as the years increase. Some of the bunches are several feet across and constantly increasing in size. When untouched by plow or mower these grasses form a lusty growth, frequently reaching a height of six or seven feet, yielding two tons of hay to the acre.

Such meadows could still be retained. The native prairie sod would afford equally valuable pastures but for the over-stocking. This native sod at one time not only contained a large number of species of different grasses as rich in nutrient qualities and produced as bountiful crops as any pastures east of the Mississippi, affording a great source of revenue. But during the last decade this has changed. Jared G. Smith*

*L. c. 311.

says: "It was a magnificent legacy to the rancher and the farmer. To the one it promised food for a million cattle; to the other it proved the golden possibilities of a soil that would bring fourth bountiful harvests."

H. L. Bently,* speaking of the conditions of speculation and overstocking in Texas when the large pastural belt of the central part of that state was opened by the Texas & Pacific R. R., says: "Range rights, herds of cattle and flocks of sheep changed hands at fabulous prices. Men of every rank were eager to get into the 'cow business.' In a short time every acre of free grass was stocked beyond its fullest capacity. Thousands of cattle or sheep were crowded on the ranges where half the number was too many. The grasses were entirely consumed; their very roots were trampled into the dust and destroyed. In their eagerness to get something for nothing, speculators did not hesitate at the permanent injury, if not total ruin, of the finest grazing country in America

From that day to the present little intelligent effort has been made to improve the pastures and again cover them with the rich vegetation which the soil is capable of supporting. It is not yet too late to remedy the evil, but no time is to be lost."

Happily, however, the state of Iowa is in a region with sufficient rainfall to insure permanent meadows and pastures of the more improved cultivated grasses. In western Wisconsin, bordering on the state of Iowa, I have known meadows and pastures of blue grass which have been in use more than a quarter of a century and to-day are as productive as when started. These meadows and pastures consist of blue grass, timothy, orchard grass, red top, red and white clovers. One hundred and sixty acres of pasture on my father's farm will support 100 head of cattle during the season. The conditions are somewhat exceptional since it is partially under irrigation. The broken hillside meadows, while not so productive, still are most valuable for pasture and hay purposes; they have not deteriorated. These same conditions prevail in Allamakee county where the conditions are very similar. In central Iowa there are meadows which have been in continuous use for a long period of time. The college campus, a considerable body of land, has been in sod for twenty-six years. This blue grass sod is as firm as any pasture in central Iowa. The conditions

*A Report upon the Grasses and Forage Plants of Central Texas. Bull. U. S. Dept. Agrl. Div. of Agros. 10:9.

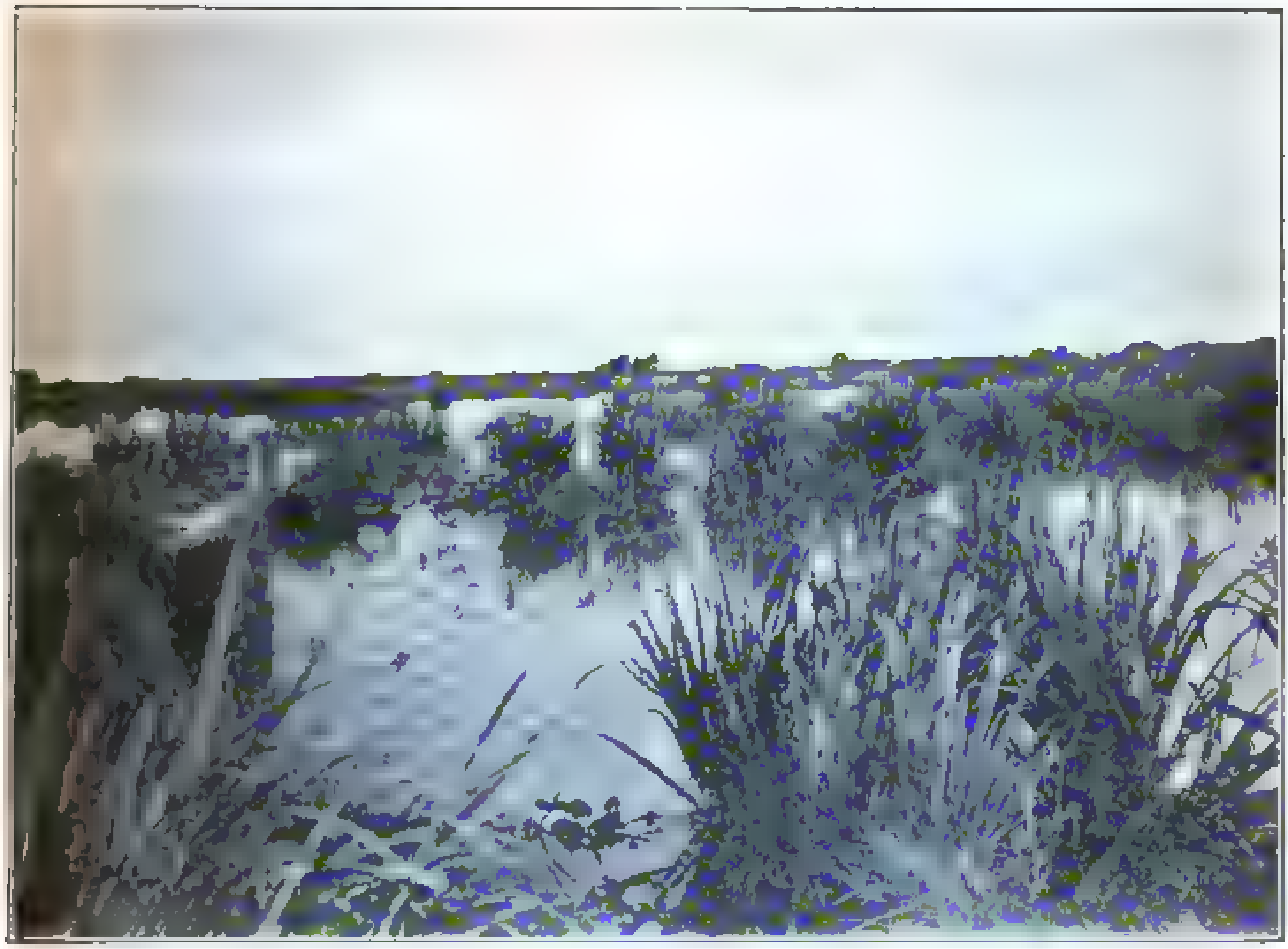


Fig. 142. Swamp grasses in western Iowa, along the Missouri. *Phragmites* and *Phalaris*

prevailing are somewhat different from those in a pasture as it is not cropped by live stock. It is, however, cut two and three times a year. There can be no question that a pasture treated carefully and judiciously will show a continuous improvement from year to year. It is a mistaken policy to destroy a blue grass pasture when it is once well started. It should be retained. It may be maintained at a much less expense than when planted with corn. Though it may produce little most seasons during the months of July and August, yet taken year after year it is much more profitable than an acre of corn. Timothy, of course, is not adapted for pasture purposes, and may be turned under after the second season. Hungarian brome grass though not tried extensively as a pasture grass will, no doubt, prove much more valuable for the pasture than timothy.

Mr. MacKay* who has had some experience with this grass in the northwest territories says it is well adapted for grazing purposes.

*Rep. Experimental Farms. 1896·396

Sowing of grass seed.—The saving of grass seed is one of the many important questions connected with a meadow or a pasture. Storer* says: "Every farmer would like to know what kinds of grasses are best adapted to his own particular fields, and to know just what conditions the soil should be brought to in order to the utmost economy of production both as regards fertility, firmness, and fineness of tilth and in respect to moisture, and the amount of sowing." It is important to know what soil is best adapted for certain grasses as well as the amount of seed to be sown per acre. The depth at which seeds should be planted is an important problem for the farmer to consider. For our agricultural grasses it is important to have the soil well drained. The drainage need not be as thorough as for the cultivated cereals. Blue grass, timothy, orchard grass and awnless brome grow successfully on any of our prairie soils. They are not nearly so successful on hard pan soil. In starting a meadow or pasture the soil should be well prepared. It is better to start the meadow or pasture on soil which has been cultivated with cereal crops for several years. A well cultivated corn crop followed by wheat or other cereal crop will put the field in excellent condition. The field should be in a good state of fertility. For Iowa conditions it is not usually necessary to apply manure. If the soil is in good condition, the next important step to consider is the time to sow. On this point opinions differ greatly. In New England as Storer† tells us the practice of farmers has greatly changed in regard to the seeding of grass fields. Formerly spring was thought to be the best time of the year and this notion still persists in Maine. It is still the custom in many other parts of northern United States. Conditions in different sections must modify the practices of farmers in this regard. In northeastern Iowa along the Mississippi, western Wisconsin and southeastern Minnesota, the fall is certainly advisable.

Thomas A. Williams‡ says: "In Nebraska and the Dakotas very fine stands of timothy are often obtained by sowing in the fall on millet stubble. In this case the land is given a thorough coating of well-rotted stable manure, and is plowed very deep and as late as possible, so as to kill all the weeds that may start. The millet is cut early and the timothy is sown

*Agriculture in some of its relations with Chemistry. 3:462.
†Agriculture in some of its relation to Chemistry. 3:460.
‡Timothy in the Prairie Region. Yearbook U. S. Dept. of Agr. 1896:148.

Fig. 144. Olcott's turf garden, showing how grasses are selected.

directly on the stubble and covered by a thorough dragging with a heavy harrow. In this treatment the land should always be made very rich and the millet should be cut before the seed has developed. It is also a good plan to leave the stubble long, to serve as a snow-catch for the protection of the timothy. A more common practice is to manure the ground thoroughly, plow, and plant to corn or some other cultivated crop that does not draw heavily upon the soil; manure lightly with well-rotted stable manure the next spring and sow to timothy, using wheat or some other small grain as a nurse plant. The wheat is usually sown broadcast and covered with a cultivator, harrowed smooth, and the timothy sown later, and the ground rolled or gone over with a brush drag. This is one of the most successful methods. Another plan often followed is to take a field that has raised a crop of small grain (say, oats), manure heavily and fall plow, sow in spring to wheat or barley, either with drill or broadcast, and seed to timothy, either with the nurse crop or later."

Professor Shelton* recommends sowing grass seed in early spring after the rains set in. In the northern states grass seed should be sown in the fall. Grass seed should not be covered deeply, as the seed usually has not sufficient nourishment to push through the soil when covered deeply.

Professors Wilson and Curtiss† found that timothy raked in on April 9th made its appearance on April 27th; that covered one inch deep was not all above the ground; the same conditions prevailed. They state that seed covered two inches deep was deeper rooted and hence stood the drouth better.

In the south‡ nearly all perennial grasses will do better when sown in August and September. This enables the roots to become well established before frost, and next season helps to keep the weeds down. The only uncertain factor in sowing grass seed in the fall is that many years the fall is so dry during September that the soil cannot be properly prepared and the seed sown in time to give the plants a chance to grow before frost. When winter sets in, the young plants should be strong and vigorous and well rooted, as the frost during the winter will destroy many plants. If the plants are well started they will make a much better showing than spring sown, as the

*Beal. Grasses of N. Am. 1:245. (Ed. 2)

†Bull. Iowa Agrl. Exp. Sta. 19: 610.

‡Lamson-Scribner. Southern Forage Plants. U.S. Dept. of Agrl. Farmers' Bull. 102: 6.

drouth is apt to injure the young plants which are not well rooted, since the roots are very near the surface of the soil.

Professors Wilson, Curtiss and Kent* found in some experiments made at Ames with timothy, tall meadow oat grass, orchard grass and Hungarian brome that the earliest seeding did best, good results coming from it in every case. No variety failed when sown early. The late sowings of all the varieties were failures, or partial failures. The earliest grass was sown on March 23d, the latest on May 12th.

Opinions differ in regard to amount of seed to be sown per acre. The amount of timothy sown varies from five to seven quarts per acre. The following table shows how much is usually sown.

AMOUNT OF GRASS SEED TO SOW, AND NUMBER OF GRASSES IN ONE POUND OF SEED.

NAME.	Number of grains in one pound of seed.	Amount to sow per acre in pounds — standard quality.	Amount to sow per acre in pounds of pure germinating seed.	Weight per bushel in pounds.
Timothy	1,170,500	16.	14.	48.
Hungarian brome grass	137,000	44.	35.60	14.
Bluegrass	2,400,000	17.5	8.4	......
Red top	603,000	9.7	7.	8.32
Orchard grass	579,500	35.	......	12.16
Meadow fescue	318,200	52.	......	12.26
Tall meadow oat	159,000	70.	34.3	10.
Rough-stalked meadow grass	3,000,000	17.5	8.75	11.17

Maintaing a pasture or meadow.—Frequent complaints are made about pastures and meadows running out. There are many causes for this. Many insects are responsible for the destruction of the sod. The writer has seen acres of a firm knit sod destroyed by the May beetle (*Lachnosterna fusca*). Many other insects are active agents in the destruction of meadows and pastures but space will not permit us to describe the numerous insect enemies of grasses. Those who desire information along this line should consult the works of ento-

*Bull. Iowa Agrl. Exp. Sta. 15: 284.

mologists like Osborn*, Cook†, Howard and many others. Attention has been called to fungus enemies in another connection. Weeds are also important in destroying the sod, but these come in because of the injury to the sod and overstocking of the pasture. If the pasture is overstocked the better grasses cannot maintain themselves. This is particularly true of the native prairie pastures where some species stand grazing much better than others. Bushy blue stem of pastures does not stand grazing well, and consequently soon give way to weeds or more worthless annual grasses. Squirrel-tail grass is frequent in the best blue grass meadows in this state and farmers frequently complain that this grass is running this fine pasture grass out. Only one thing can be done for this and other annual weeds and that is to cut them off before they flower. Professor Williams‡ in a paper on this subject states that "An experiment made at the Kansas Station in 1892 shows what a thorough stirring up of the soil will do for an upland prairie pasture. The experiment was made on a pasture in which the grasses had been dying out for some time and the weeds were beginning to appear in abundance. It had been reduced to this condition by drouth and overpasturing. The surface was thoroughly loosened up by driving a weighted disc harrow over the field in several directions. The pasture was sown to a mixture of orchard grass, meadow fescue, blue grass, timothy, red top, clover, and alfalfa, which was harrowed in and a roller was driven over the field to level the surface and firm the ground. The seed germinated quickly and the tame grasses made an excellent start, but by September the wild grasses had crowded them out and held complete possession of the field. In this case the stirring of the soil and the season's rest not only enabled the prairie grasses to recover and to overcome the weeds, but to crowd out a good stand of tame grasses as well."

In this state the blue grass comes in naturally in wild meadows and pastures, especially in pastures. Many farmers have succeeded in starting cultivated grasses in native sod by sowing blue grass, timothy and clover on the sod by thoroughly stirring the soil.

*Bull. Iowa Agrl. Exp. Sta. 13:95. Osborn has published numerous papers on this subject.

†The Enemies of Grasses and Clovers in Beal. Grasses of N. Am. 1:369 (Ed. 2).

‡The Renewing of Worn out Native Prairie Pastures. Circ. U. S. Dept. Agrl. Div of Agrost. 4: See Georgeson, Burtis and Otis. Renovating a prairie pasture. Bull Kansas Agrl. Exp. Sta. 48:43.

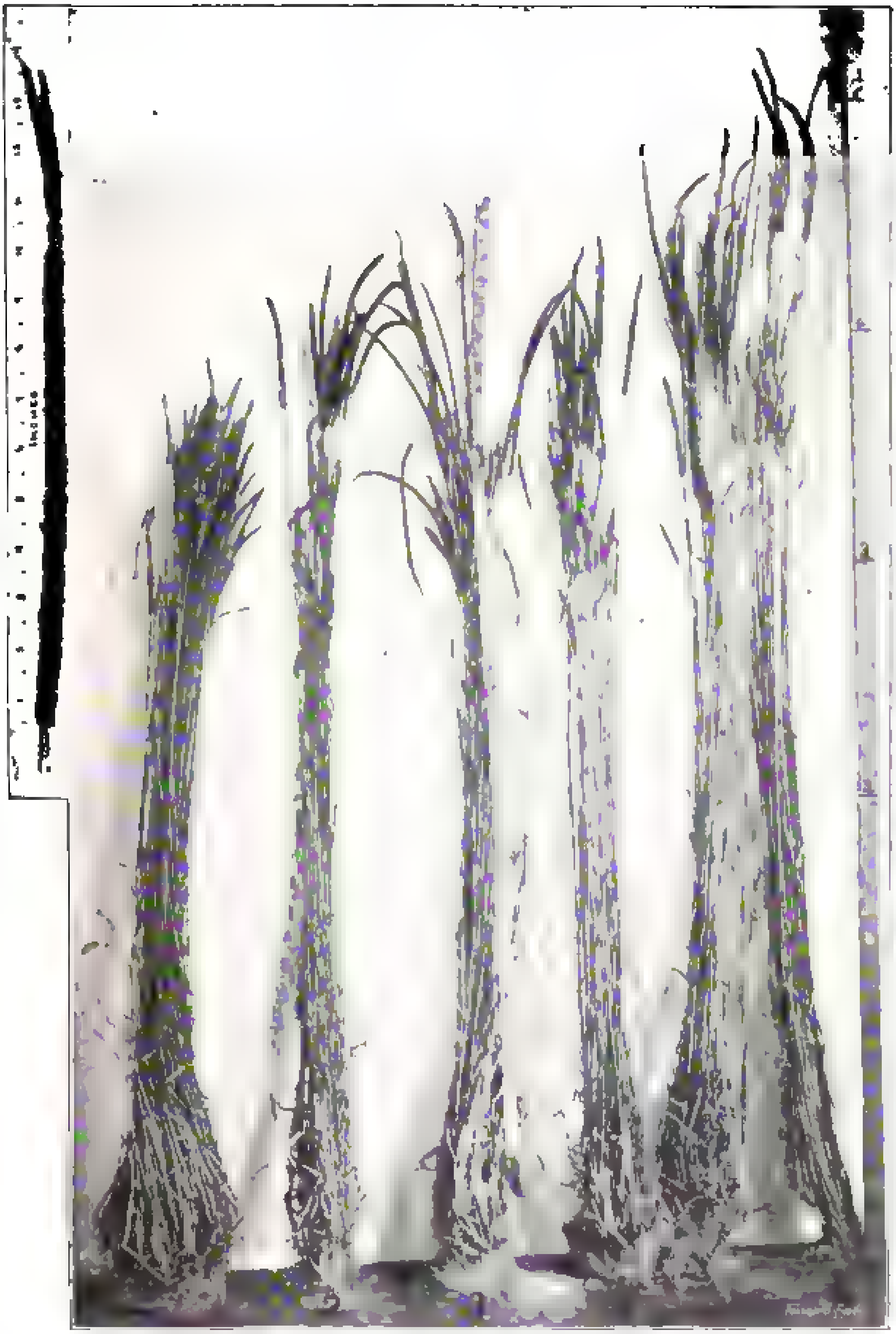


Fig. 145. Different forms of timothy. From the best of these, the future timothy must come. (Hopkins West Virginia Exp. Sta. Proc. Soc. Prom. Agrl. Science.)

MEADOW AND PASTURE GRASSES.

Little positive can be said of the early cultivation of grasses, as there is much uncertainty about the specific kinds used by the early agriculturists.

So long as pastoral conditions prevailed there was no need of cultivating grasses or giving much attention to the subject, but the strong competition and the improving of tilled land called for their cultivation. The ancients cultivated some legumes, but special attention was not given to grasses, except cereals. Sinclair* states that: "Distinguished agriculturists and farmers agree in the opinion that the knowledge of the comparative merits and value of all the different species and varieties of grasses, and, consequently of the best mode of cultivating them, is very much behind that of the other branches of practical culture."

Very little has been done in this country to select and breed grasses as we do cereals and other plants. Olcott† of Connecticut has a turf-grass garden at South Manchester. His plan is to make of pure grass a commodity, capable of being transferred. In these sods, also, he has a valuable object lesson in turf-grass culture.

Professor Hopkins‡ of the West Virginia Agricultural Experiment Station, has made some interesting observations on the variability of timothy. Some mature early and some much later. There was also a difference in the amount of hay produced. The plants of Mr. Hopkins were propagated by seed. Professor Hays§ also shows that much may be done with some of our forage plants, notably timothy.

There are many forms of grasses, some no doubt much more valuable than others. As an illustration, bluegrass runs into many forms, but no effort is made to plant the best bluegrass. Any kind will do as long as it is bluegrass. So of timothy, which runs into many forms; the best is never planted. All kinds of timothy seed will do. There can be no question that our hay crops and pastures could be largely increased if intelligent selection were carried on. For years' experiments have been carried on with various grasses, and though it has

Hortus Gramineus Woburnensis. 15. London Ed.

†Rep. Conn. Bd. of Agrl. 1898: 136.

Publication of Grasses. The Am. Enterprise, July 14, 1900.

To Ship Grass Sods. The Hartford Courant, Dec. 9, 1898.

‡Some Observations on Varieties of Timothy (*Phleum pratense, L.*) Proc. Soc. Prom. Agrl. Sci.. 1895: 29. *Pl. 11.*

§Bull. Minn. Agrl. Exp. Sta. 20: 44.

been repeatedly shown that many of these are worthless, the same experiments are repeated. Certain grasses are adapted to particular soils and climates. De Laune* names the following five coarse grasses as best suited for England: *Dactylis*

Fig. 146. Blue grass, *Poa pratensis*. The best of all our pasture grasses. Two types. Blue grass offers an excellent chance for improvement, as the cut shows

glomerata, *Festuca pratensis*, *F. elatior*, *Phleum pratense*,, *Alopecurus pratensis*. The most valuable of the finer grasses are: *Cynosurus cristatus*, *Festuca duriuscula*, *F. ovina*, *Poa trivialis*, *Agrostis stolonifera* and *Avena flavescens*. Beal† gives following

*Jour. Roy. Agrl. Soc. 1882: 229. Beal Grasses of N. Am. 1: [illegible]. (Ed. 2)
†Grasses of N. Am. 1: [illegible]. (Ed. 2.)

grasses for permanent pastures or meadows for the north: *Dactylis glomerata*, *Arrhenatherum avenaceum*, *Festuca elatior*, *F. pratensis*, *Alopecurus pratensis*, *Phleum pratense*, *Poa pratensis*, *Agrostis alba*. For marshes he gives: *Agrostis alba*, *Festuca pratensis*, *F. elatior*, *Poa serotina*, *P. pratensis*, *Alopecurus pratensis*. and *Calamagrostis canadensis*.

Lamson-Scribner* gives the following as the more important grasses for the south: Bermuda grass, fescue grass (*Bromus unioliodes*), *Lolium italicum*, *Poa arachnifera*, teosinte (*Euchlaena*), *Panicum maximum*, *Agrostis alba*, and *Andropogon sorghum*.

Hitchcock† lists the following as the more important of the native grasses of Kansas: *Tripsacum dactyloides*, *Spartina cynosuroides*, *Panicum virgatum*, *P. crus galli*, *Andropogon furcatus*, *A. scoparius*, *A. hallii*, *Andropogon nutaus*, *Phalaris arundinacea*, *Aristida purpurea*, *Muhlenbergia glomerata*, *Sporobolus cryptandrus*, *Sporobolus airoides*, *Cynodon dactylon*, *Bouteloua oligostachya*, *B. hirsuta*, *B. racemosa*, *Chloris verticillata*, *Triodia cuprea*, *Poa pratensis*, *Koeleria cristata*, *Eatonia obtusata*, *Uniola latifolia*, *Distichlis maritima*, *Agropyron spicatum*, *E. canadensis*, *E. virginicus*.

For the state of Iowa the following are the more important grasses: *Poa pratensis*, *Phleum pratense*, *Bromus inermis*, *B. breviaristatus*, *Dactylis glomerata*, *Agropyron spicatum*, *Andropogon provincialis*, *A. nutans*, *Agrostis alba*, *Calamagrostis canadensis*, *Panicum virgatum*. For general cultivation *Poa pratensis*, *Phleum pratense*, and *Bromus inermis* are the most valuable. For shaded ground *Dactylis glomerata* and *Agrostis alba*. For low grounds, *Agrostis alba*, *Poa serotina*, *P. pratensis*, *Calamagrostis canadensis*. For dry hills, *Bouteloua oligostachya*, *B. racemosa*. For alluvial bottoms, *Andropogon provincialis* and *Spartina cynosuroides;* the former is also suited for upland prairies. For the loess of western Iowa, *Agropyron spicatum*, *Andropogon scoparius*. It will be seen from this list that it is difficult to recommend particular grasses unless the soil, drainage and other facts are taken into consideration.

In the adjoining state on the west, Nebraska, Professor Bessey‡ enumerates quite a number of wild species that are valuable. Of the Iowa species his list contains the following: Wild wheat grass, (*Agropyron spicatum*) *Bromus breviaristatus*,

*So. Forage Pl. Farmers' Bull. U. S. Dept. of Agrl. 102:9.
†Native Agricultural grasses of Kansas. Bull. Kansas Agrl. Exp. Sta. 87:5.
‡The Grasses and Forage Plants of Nebraska. Neb. State Board of Agr. 1889:11.

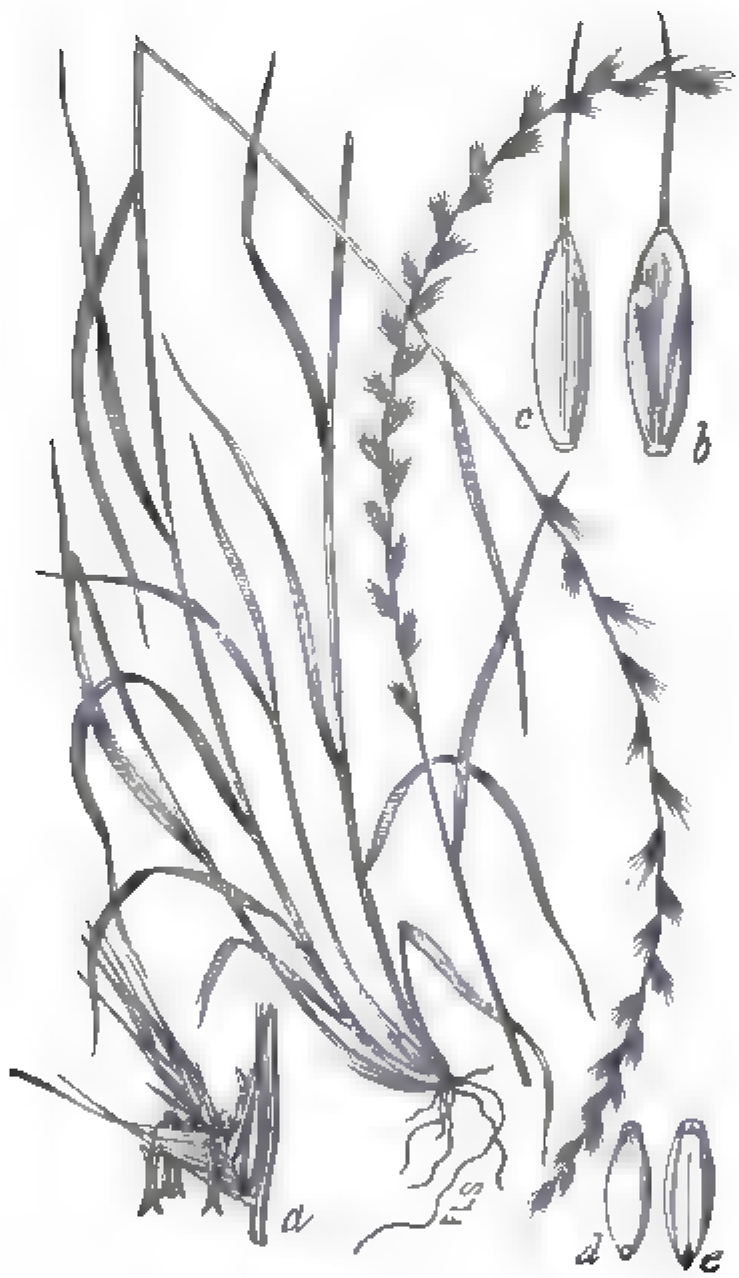


Fig. 147. Italian Rye Grass, *Lolium italicum*. (Div. Agrost. U. S. Dept. Agric.)

Poa serotina, *Bouteloua oligostachya*, *B. racemosa*, *Andropogon provincialis*, *A. scoparius*, *Panicum virgatum;* and of the cultivated species, orchard grass, timothy, Kentucky blue grass, wire grass, (*Poa compressa.*)

Professor Williams* states that the principal grasses of the stock raising regions of the Dakotas are the gramas, buffalo grass, the blue joints, the sand grasses, western wheat grass, western quack grass, needle grass and feather bunch grass. Western wheat grass and western quack grass furnish most of the hay except in the moister bottoms, where the blue joints, big sand grass and cord grass are more or less abundant.

ITALIAN RYE GRASS (*Lolium italicum*), A. Br.—The cultivation of Italian rye-grass (*Lolium italicum*) first began in Lombardy,† where it has long been cultivated, espe-

*Grasses and Forage Plants of the Dakotas. Bull. U. S. Dept. Agri. Div. Agrost. 6:6.
†Stebler, Schroter & McAlpine. The Best Forage Plants. 26.

Fig. 146. Perennial Rye Grass, *Lolium perenne*. (Div. Agrostol. U. S. Dept. of Agrl.)

cially in irrigated districts. At the beginning of this century it was cultivated in France. Lawson introduced it into Scotland in 1840. In England Dickinson introduced it somewhat later, the moist climate of England being suitable to its growth. Although this grass is valuable in some sections of our country, it has never commended itself to Iowa farmers. It is not hardy, nor a drouth resister, and is at most a very short-lived grass.

In the eastern states it is highly recommended for calcareous soils or for moist, loamy sands. Even then the grass only lasts for two or three years.

Prof. F. Lamson-Scribner says: "Italian ray, or rye, grass is an excellent grass for rich and rather moist lands. It is a very rapid grower, forms a dense turf, and in Europe is regarded as one of the best grasses for hay."

The chemical alalyses made at several stations show:

	Water. (3)	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Mississippi (1):						
Avg. of two samples..	80.72	4.04	18.30	27.17	11.43	39.06
Northern grown (1):						
Avg. of thirty-three samples..	73.16	5.00	11.40	25.10	9.20	49.30
Mississippi (2):						
Young, cut in April..........	....	3.34	19.12	28.32	12.02	37.20
Young, cut in July..	..... .	4.74	17.49	26.02	10.84	40.91

ORCHARD GRASS (*Dactylis glomerata*), L.—The cultivation of orchard grass (*Dactylis glomerata*) began in Virginia a few years previous to 1764. About this time it was introduced into England. At the beginning of this century it attracted considerable attention, especially because of the success attained with it by Mr. Coke, of Norfolk. The seed was first extensively collected by Rogers, Parker and Gibbs. It was introduced into Switzerland* in 1808, but not grown on an extensive scale until 1860. It has become one of the chief grasses of the British islands. Orchard grass is an introduced species in many parts of the state. On the College farm it occurs with other grasses in shady places. In the eastern states it has long been known as a valuable grass, and in England it has long been known as one of the best of the pasture grasses, especially in the regions best known for their fine stock, as in Devonshire and Lincolnshire. In this country it has had many admirers. Buel† says of it: "The American cock's foot or orchard grass, is one of the most abiding grasses we have. It is probably better adapted than any other grass to sow with clover and other seeds for permanent pasture or for hay, as it is fit to cut with clover and grows remarkably thick when cropped by cattle. Five or six days' growth in summer suffices to give a good bite. Its good properties consist in its early

1. Exp. Sta. Rec. 6: 101.
2. Ann. Rept. Miss. Exp. Sta. 8: 91. 1895.
3. Where percentage of water is given, it is the per cent of water in the samples as collected, and other per cents are for dry materials.

*Stebler, Schroter & McAlpine. The Best Forage Plants. 31.

†Grasses and Forage. Pl. 66.

and rapid growth and its resistance to drouth, but all agree that it should be closely cropped. Sheep will pass over every other grass to feed upon it. If suffered to grow long without being cropped, it becomes coarse and hard."

Orchard grass, although widely distributed in this state, is grown very little for forage purposes. There are several reasons for this. One is that it forms little tussocks which make

Fig. 149. Orchard grass, *Dactylis glomerata*. A most excellent grass, well adapted Iowa conditions. (After F. Lamson-Scribner. Div. Agrost. U. S. Dept. of Agrl.)

it decidedly objectionable for some purposes. It is frequently very uneven. It is unequaled as a palatable grass, and those who have used it in this state speak of it in the highest terms, but the farmers have become so accustomed to growing timothy that this grass has scarcely been given a fair chance in this state.

Chemical composition:

The following analyses of orchard grass were made in the laboratory of this station:

Sample 1. April 24, 1896, 7 to 16 inches high.
Sample 2. May 4, 1896, 14 to 16 inches high.
Sample 3. May 18, 1896, sample very wet.
Sample 4. May 26, 1896, 38 to 42 inches high
Sample 5. June 5, 1896, 28 to 30 inches high.
Sample 6. June 17, 1896, 40 to 45 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract
Sample 1	85.52	.77	4.38	(3.39)	3.33	2.23	3.77
Sample 2	84.54	1.02	3.15	(2.14)	4.15	1.93	5.21
Sample 3	83.25	.86	2.51	(2.31)	5.80	1.77	5.81
Sample 4	78.18	1 35	2.95	(2.42)	7.17	2.36	7.99
Sample 5	78.74	1.00	3.38	(2.33)	8.63	2.68	5.57
Sample 6	69.78	1.22	2.75	(2.55)	11.71	2.58	11.96

WATER FREE SUBSTANCE.

Sample 1	5.36	30.25	(23.45)	23.01	15.38	26.00
Sample 2	6.62	20.37	(13.83)	26.88	12.48	33.67
Sample 3	5.09	15.01	(13.80)	34.59	10.59	34.72
Sample 4	6.20	13.50	(11.09)	32.85	10.84	36.61
Sample 5	4.72	15.91	(10.98)	40.60	12.62	26.15
Sample 6	4.04	9.11	(8.44)	38.76	8.54	39.55

From these results it is readily seen that there is a decrease in the amount of water present in the samples as growth increases. In the dry condition we find that the fat varies in the sample from 6.62 per cent to 4.04 per cent. There is not a regular decrease in this constituent, but it is somewhat irregular. Regarding the amount of protein we might say that there is a regular decrease with one exception from 30.25 per cent to 9.11 per cent. With the crude fiber there is a tendency for the amount to increase as the plant grows older as we have in the first sample 23.01 per cent and in samples 5 and 6; 40.60 per cent and 38.76 per cent respectively and the same may be said regarding the amount of nitrogren free extract increasing from 26 per cent to 39.55 per cent with one exception.

The following analyses of other states are added for comparison:

SAMPLE FROM.	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Green fodder, in bloom (1).....	73.00	.90	2.60	8.20	2.00	13.30
Iowa (2):						
Cut June 9, just out of bloom	70.07	.71	2.31	10.15	3.00	13.76
Cut April 29................	*78.14	6.27	21.46	16 92	13.22	42.13
Cut May 10..................	*75.58	6.36	18.50	19.76	12.27	43.11
Cut May 20..................	*72.43	4.62	12.34	21.75	10.23	51.06
Cut May 30.............. ..	*71.90	2.65	9.19	29.48	10.00	48.68
Cut June 9..................	*70.07	2.36	7.71	33.90	10.02	46.01
Louisiana (3)	12.82	3.70	7.82	28 35	10.75	36.56
North Carolina (4)............	5.25	2.60	6.69	38.43	5.90	41.43
North Dakota (5)..............	15.35	3.53	8.12	31.14	6.13	35.73
Oregon (6)....................	11.80	2.26	8.17	38.33	5.90	33.54
Storrs, (Conn.) (7):						
Average 16 analyses.........	68.60	1.30	3.00	10.70	2.80	13.60
Utah (8):						
Average of 3 analyses	14.82	2.62	3.52	30.01	7.93	50.66

TIMOTHY (*Phleum pratense*), L.—The cultivation of timothy (*Phleum pratense*) first began in America. Sinclair, in his *Hortus Gramineus Woburnensis* says: "In the annual register for 1765 we find that it was much recommended about fifty years ago, under the name of timothy grass, and Mr. Wynch is said to have brought it from Virginia in 1763." It received this name from Mr. Timothy Hanson, who first brought its seed from New York to Carolina. In America, at this time, it was also known as Herd grass. In 1815 it was considered the best grass in the province of Canada. Jessen,† in his work on the grasses of Germany, gives the date of general introduction into that country as 1815, but Peter Wynch in 1760, president of the Agricultural Society of England, obtained the seed of this grass and several others from North America. Its general cultivation began in England soon after 1765. On the conti-

1. U. S. Dept. of Agrl., Handbook Exp. Sta. Work. 1893. 386.
2. Bull. Iowa Agrl. Exp. Sta. 11:453, 476.
3. Bull. La. Agrl. Exp. Sta. II. 19.
4. Bull. N. C. Agrl. Exp. Sta. 90.
5. Bull. N. D. Exp. Sta. 15.
6. Bull. Oregon Agrl. Exp. Sta. 1895. 39.
7. Ann. Rept. Storrs Agrl. Exp. Sta , Conn. 1896: 280.
8. Rept. Exp. Sta. Utah, 1893: 254, 255.

*Per cents given are all for water-free material except per cent of water.

†Deutschland's Gräser und Getreidearten. Leipzig. 48. 1863.

nent of Europe it was cultivated a few years later. A further chapter of its history is given by Flint:* "It is frequently called Herd's grass in New England and New York, and this was the original name under which it was cultivated. The name was derived from a man of that name who, according to Jared Elliott, found it growing wild in a swamp in Piscataqua, N. H.,

Fig. 159. Timothy, *Phleum pratense.* The best meadow grass for Iowa, and a general favorite among farmers. (F. Lamson-Scribner. Div. Agrost. U. S. Dept. Agrl.)

more than a century and a half ago, and began to cultivate it. In Pennsylvania and states further south this name is applied to *Agrostis vulgaris,* or the red top of New England." Timothy is pre-eminently the grass grown in this state for meadow purposes. No other grass stands in such high favor as does this. It is highly productive, stands drouth well, and is not subject

*Flint. Grasses and Forage Plants. 34. (Rev. Ed.)

to winter-killing. There is a decreasing yield from year to year, and it is found advisable to turn old fields under. Unless it is mixed with other grasses it is usually not best to keep a timothy meadow longer than three years. Although Professor Williams* states that there are upland meadows in Nebraska which have been in constant use for fifteen years or more, and in that time have not failed to yield paying crops. In this state at least the timothy meadow "runs out" and is replaced by bluegrass. I have, however, seen pastures and meadows in Wisconsin that have been in constant use for fifteen years where considerable timothy could be found. With the timothy, however, there was much bluegrass and clover. Professor Williams† says: "Timothy is often used in reclaiming worn-out native meadows and pastures, and with proper treatment very good results are obtained. It seldom yields well in pastures, however, for more than two or three years in succession unless the land is very rich and moist. It is, therefore, the best plan to sow bluegrass with the timothy, and by the time the latter is pastured out the former will have occupied the land. Sowing on native turf is usually done in early spring. The seed is sown broadcast, and then the ground is gone over thoroughly with a heavy harrow. Native meadows on low, rich soil, that have become thin from continuous close cutting, may be very materially strengthened by the addition of a little timothy in this manner, as the writer knows from experience in both Nebraska and South Dakota."

In spite of the early failures, timothy is to-day one of the most valuable of all the meadow grasses grown in the northern Mississippi and Missouri valleys.

Opinions differ as to when timothy should be cut. Many farmers wait until the seeds are in the "dough" stage; some even wait longer. The farmer who waits until the seed is ripening lacks thrift. It is far better to cut just before the timothy is in bloom or during full bloom. If cut before it blooms it is much more difficult to cure. It cures better if cut just after the blossoms fall. Professor Williams‡ says: "The best hay is obtained by cutting during full bloom, or when the blossoms fall. The feeding qualities are best at full bloom, but most farmers prefer to cut a little later, as the pollen makes the hay

*Timothy in the Prairie Region. Year-book U. S. Dept. of Agrl. 1896: 147.
†Year-book U. S. Dept. Agrl. 1896: 149.
‡Year-book U. S. Dept. Agrl. 1896: 150.

'dusty,' which is avoided by waiting. It sometimes happens that, on account of lack of moisture, the first growth is light, and abundant rains in June or July may cause a strong second growth to spring up, which will not be in its prime until the first has reached an advanced stage of development. In such cases it would be more profitable to cut late, provided the proper precautions are observed as to the condition in which the sod should be left. There is a growing sentiment in favor of cutting timothy with the self-binder for hay as well as for seed, and the practice has much to commend it. With right treatment the hay cures well, is much more easily handled and fed, and can be stored in a more limited space than when cut in the ordinary way."

Timothy hay may be decidedly improved by growing a small amount of clover along with it, nor is bluegrass mixture objectionable, except where present the grass must be cut early. Timothy cannot be pastured when the soil is dry, as stock is very liable to injure the bulbs, but in low meadows it stands grazing fairly well in the spring, but cattle should not be allowed to graze on it in the fall. If timothy is to be used for grazing purposes it should be in a meadow containing bluegrass, timothy and clover. The clover readily perpetuates itself and helps the timothy, in that the soil is less compact.

CHEMICAL COMPOSITION OF TIMOTHY.

Four samples of the grass were analyzed in the station laboratory with the following results:

Sample 1. May 16, 1896, 12–16 inches high.
Sample 2. May 26, 1896, 24–25 inches high.
Sample 3. June 8, 1896, 40–42 inches high.
Sample 4. June 18, 1896, 39–40 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	81.09	1.12	3.49	(2.82)	5.06	2.24	7.00
Sample 2	79.22	1.07	2.52	(2.34)	6.30	2.06	8.83
Sample 3	76.64	.83	2.28	(2.01)	8.50	1.97	9.78
Sample 4	69.87	1.41	2.63	(1.87)	11.22	2.31	12.56

WATER FREE SUBSTANCE.

Sample 1	5.92	18.44	(14.93)	26.75	11.87	37.01
Sample 2	5.14	12.15	(11.28)	30.31	9.90	42.50
Sample 3	3.59	9.77	(8.60)	36.41	8.41	41.82
Sample 4	4.68	8.74	(6.21)	37.26	7.67	41.65

From these results we can draw the following conclusions: The water content of the sample as received in the laboratory decreased from 79.22 per cent to 69.89 per cent as the growth increased. For comparison of the other constituents the results based on the dry matter will give more satisfactory results and here we find that the fat is somewhat lower in the sample of June 8th than in the other three. The amount of protein present decreases as the plant grows older from 18.44 per cent to 8.74 per cent. The same condition is present in the case of the albuminoids. The crude fiber, however, increases from 26.75 per cent to 37.26 per cent while the nitrogen free extract increases from 37.01 per cent to 42.50 per cent.

As a matter of interest the following analysis of *Phleum pratense* are selected for comparison with the results obtained from the Iowa samples:

SAMPLE FROM.	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
All analyses 68—(1)	13.29	2.50	5.90	29.00	4.40	45.00
Cut in full bloom	15.00	3.00	6.00	29.60	4.50	41.90
Cut soon after bloom	14.20	3.00	5.70	28.10	4.40	44.60
Cut when nearly ripe	14.10	2.20	5.00	31.10	3.90	43.70
Iowa (2):						
July 12, after bloom	53.25	1.31	3.38	14.45	3.36	24.25
Wild from Idaho, cut June 20, just before blooming	72.88	.50	3.30	9.07	2.40	11.85

1. U. S. Dept. of Agrl. Handbook of Exp. Sta. Work. Bull. 15:388. 1893.
2. Bull. Iowa Agrl. Exp. Sta. 11:449. 455.

SAMPLE FROM.	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Northern grown (1)	*61.58	3.10	8.00	30.70	5.40	52.80
North Dakota (2), full bloom	15.35	2.69	6.59	26.88	4.16	44.33
After seeds mature	15.35	2.36	5.34	29.65	3.65	43.65
Louisiana (3)	14.51	3.48	8.38	29.63	9.75	34.25
Mississippi (4):						
Gathered in April (dry)	....	2.85	6.51	34.17	7.63	48.84
New Mexico (5), green fodder	61.60	1.20	3.10	11.80	2.10	20.20
Oregon (6):						
Early bloom	11.19	2.20	6.02	30.35	3.98	46.25
Hay	13.00	2.50	5.90	29.00	4.40	45.00
Utah (7):						
From barn	*5.21	2.19	4.28	36.01	4.88	52.64
Green (average of 5 analyses)	*60.65	2.13	5.21	30.31	6.25	56.09
Dry (average 5 analyses)	*13.80	1.79	14.90	31.95	6.68	54.42
Cut July 2, in bloom	*36.46	3.14	8.55	49.94	7.86	35 69
South Dakota (8):						
Middle of July, 1892	....	3.58	8.84	34.39	7.39	45.80
Connecticut (9):						
Average of 4 samples	67.66	1.02	3.70	11.57	1.87	14.18
Hay	....	3.16	11.42	35.81	5.76	43.83
Hay, average of 4 early cut	....	3.92	12.20	33.85	5.70	44.33
Timothy rowen	63.28	2.06	5.57	8.99	2.95	17.15
Timothy rowen	71.07	1.77	4.95	7.19	2.41	12.61
Green fodder (average of 4)	62.78	1.30	2.75	11.88	2.14	19.15
Tennessee (10):						
Average of 13 analyses	11.82	1.95	5.66	30.68	4.81	45.08

MEADOW FESCUE (*Festuca elatior*, L.)—The value of meadow fescue (*Festuca elatior*) as a forage plant has been known for a long time. It appears to have attracted attention as early as 1761, but it was not cultivated experimentally until 1820. Stebler and Schröter† state that Judtmann speaks of it as an excellent grass in 1790. Its cultivation on the continent began about 1850 It was early introduced into this country. Although

1. Exp. Sta. Record. U. S. Dept. Agrl. 6: 101-103. 1894.
2. Bull. N. D. Exp. Sta. 15:49. 1894.
3. Bull. La. Exp. Sta. II. 19:536-562.
   Abstract in U. S. Exp. Sta. Record 4:1893. 645.
4. Rept. Miss. Agrl. Exp. Sta. 1895:92.
5. Bull. N. Mex. Exp. Sta. 17:34. 1895.
6. Bull. Oregon Exp. Sta. 39:43.
7. Rept. Utah Exp. Sta. 1893:254-255.
8. Bull. S. D. Exp. Sta. 40:68. 1894.
9. Storrs Ann. Rept. 1894:21.
   Storrs Ann. Rept. 1895:180.
   Storrs Ann. Rept. 1896:280.
10. Bull. Tenn. Exp. Sta. 9:113.

*Shows amount of water in sample in natural condition when received. The other results are for water free substances.

†The Best Forage Plants. Eng. translation. 36.

this grass has become spontaneous at several points in this state, it is not cultivated to any extent as a meadow grass. Meadow fescue makes a fine turf, but in this state has a tendency to become thin. It is less able to resist drouth than timothy, bluegrass or orchard grass. Its cultivation in this country

Fig 151. Meadow Fescue. *Festuca elatior* var. *pratensis*. A good grass in some parts of the United States, but not in Iowa. (Div. of Agrost. U. S Dept. of Agri.)

is confined chiefly to the east rn states, where it is held in high esteem. Several other species of Festuca occur in the state, but only one of these is valuable as a forage grass, the *Festuca shortii*, Kunth, which is common in native prairie meadows. The *Festuca nutans*, Willd, is an early maturing woodland species, and of very little value as a forage plant. Sheep's fescue (*F. ovina*, L.), is sometimes cultivated, and for dry, sterile soils, is a valuable grass. It is one of the common bunch grasses of the

west. The allied *F. rubra*, L., has been naturalized at several points in this state. It is superior to Sheep's fescue because of its creeping rootstocks One of the most valuable of all the Festucas is the great bunch grass (*F. scabrella*, Torr.) which is a native of the Rocky mountain regions, where it occurs in large open parks. It is an ideal grass for winter forage, and should be cultivated in Iowa.

Fig. [illegible] Group of Festucas. All common in Iowa. The *F. nutans* occurs in woods; the *F. shortii* in wet meadows; the *F. tenella* in sandy soil.

BLUEGRASS (*Poa pratensis*, L.)—In Europe little has been done with the cultivation of bluegrass (*Poa pratensis*). Sinclair, writing on this grass in 1824, says: "There are many other grasses superior to this one. It comes early in the spring, but

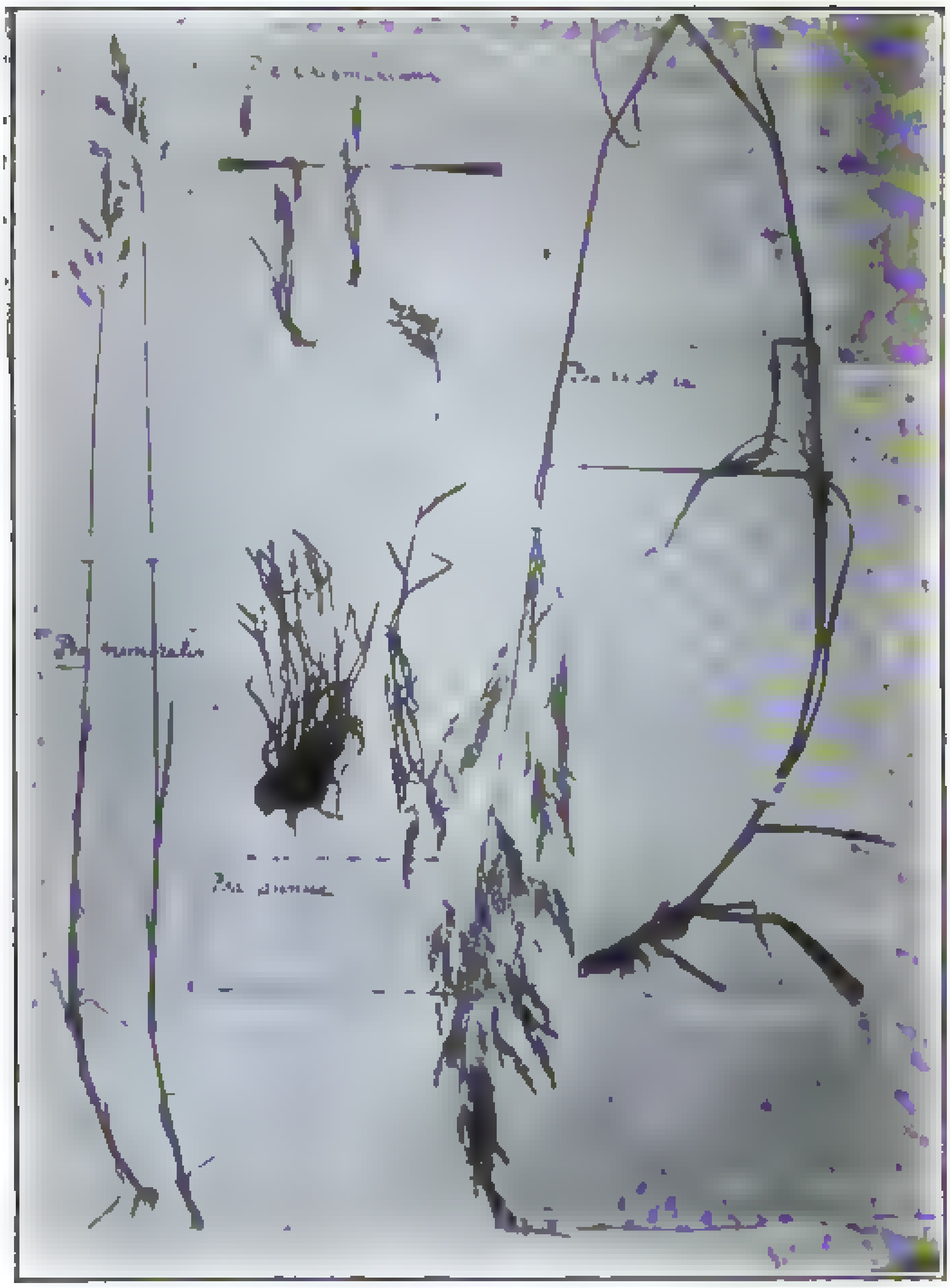


Fig. 152. A group of meadow grasses. Fowl meadow grass, (*Poa serotina*) to the right, a very productive grass, common in low grounds. *P. nemoralis* a g: od mountain grass, rarely occurring in this state. *P. annua*, an introduced grass in lawns. *P. Chapmaniana* occurs in southeastern Iowa.

its product is inconsiderable, compared to many other grasses. Its strong creeping roots exhaust the soil very much; after mid-summer the herbage is slow in growth after being cropped. It is the property of all creeping roots to scourge the soil, and when plants with fibrous roots can be substituted in place of these, with an equal prospect of advantage, in regard to early growth, produce and nutritive qualities, it will be found to repay the labor with interest." It appears first to have been cultivated about the middle of the last century under the name of Birdgrass. It has long been known as a valuable grass in

New England, where probably it was largely self-sown. In the west it was contemporaneous with the settlement of the country. Bluegrass is the pasture grass par excellence in Iowa. The excellence of Iowa stock is largely due to the fine bluegrass pastures. Bluegrass comes on early in the season and during the latter part of May and early in June is ready to bloom In order to get the full advantage of bluegrass as a pasture grass it should not be allowed to seed, as that takes away much of the valuable nutritious qualities contained in the grass. In this state bluegrass is seldom used for meadow purposes, but in parts of Wisconsin, especially the western part, it is frequently used for this purpose. When used for meadow purposes it should be cut early, and especially when the meadows are moist, this grass may then be cut a second time. On an irrigated field of my father's farm in western Wisconsin bluegrass has been cut three times. I know of no other grass which makes such valuable fodder as bluegrass, especially when mixed with a small amount of clover and cut early. Cattle are very fond of it, and it makes an excellent grass for dairy purposes. Although bluegrass may not be a good pasture grass during the latter part of July and August, yet it has many commendable features, even though the pastures may look dry and bare. The small leaves are highly nutritious and in many cases cattle apparently thrive and grow fat on pastures that seem to contain but little. This was especially noticeable in 1894, when the season was remarkably drouthy over a large section of the state. In many cases where pastures were not cropped too close, horses and cattle fattened.

After the fall rains, during the latter part of August and early September, bluegrass continues to grow rapidly. The brown pastures of August again take on a green look, since the cool nights and sufficient moisture are favorable for its rapid growth. Cattle may therefore feed on it until cold sets in. Many Iowa farmers are familiar with the value of bluegrass as a winter pasture grass. Hundreds of acres are utilized in this way. A considerable amount of forage is obtained for cattle and horses during open winters. Chemical analyses show that the brown and sere grass leaves are not without their nutrient value, and we cannot pass the subject of bluegrass without saying something of its use in the central and southern part of the state as a winter forage plant. When speaking of winter pasturage in Iowa, the farmer refers to bluegrass. It is a well

known fact that cattle do remarkably well on this grass in the winter. Though it has lost some of its nutritious qualities, it is highly relished and serves a most excellent purpose in keeping the digestive organs of the animals in good condition. With a good winter pasture of bluegrass it will be unnecessary to use the "stock foods" to regulate the organs of secretion. Farmers should not lose sight of the fact that overstocking is injurious. To be in good condition for the winter it should not be overstocked in September and October. Other grasses have been tried in this way. Texas bluegrass has received considerable notoriety in this respect, and while perfectly hardy at Ames, Iowa, nothing can be said about its use in central Iowa for this purpose, since it has not been extensively tried. The great point in favor of bluegrass as a pasture grass is that it is very rarely injured by cold, is hard to kill during dry weather or by the hot sun, the tramping of hoofs or close mowing. The pasture is continually increasing in value as it becomes older. The writer is familiar with pastures which have been in bluegrass for a quarter of a century, and they yield as abundantly to-day as at any time in the history of the meadow.

CHEMICAL COMPOSITION.

The samples analyzed in this station are given in the following tables:

Sample No. 1. April 14, 1896, young, 1 to 4 inches high.
Sample No. 2. April 29, 1896, 3 to 10 inches high.
Sample No. 3. May 6, 1896, beginning to head out, 14 to 18 inches high.
Sample No. 4. May 18, 1896, very wet, headed, 14 to 15 inches high.
Sample No. 5. June 1, 1896, 31 to 32 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	77.78	1.36	8.66	(6.00)	3.61	2.91	5.68
Sample 2	78.96	1.03	4.42	(3.78)	5.22	3.06	7.31
Sample 3	76.18	1.04	4.79	(3.59)	5.49	2.65	9.85
Sample 4	78.50	.97	3.26	(3.14)	6.66	2.54	8.07
Sample 5	73.46	2.10	3.84	(2.35)	8.74	3.05	8.81

WATER FREE SUBSTANCE.

Sample 1	6.13	38.98	(26.99)	16.23	13.10	25.56
Sample 2	4.90	21.02	(17.95)	24.71	14.53	34.84
Sample 3	4.25	20.11	(15.07)	23.06	11.11	41.47
Sample 4	4.51	15.18	(14.58)	30.96	11.80	37.55
Sample 5	7.91	14.46	(8.83)	32.92	11.48	33.23

In the above results we find that the amount of water present in the grass as received in the laboratory is very constant indeed, the highest being 78.96 per cent and the lowest 73.46 per cent, a difference of only 5.5 per cent. In the comparison of the results of the analyses based on the dry matter, we find, in the fat content, that the amount decreases comparatively little as the grass matures. However, with the amount of protein present there is a marked decrease from 38.98 to 14.46 per cent, and in the albuminoids from 26.99 per cent to 8.83 per cent. The crude fiber increases on the contrary from 16 23 per cent to 32 92 per cent. The amount of nitrogen free extract present varies greatly. There is no constant increase but it varies from 25.56 to 41.47 per cent.

The following analyses have been selected for comparison with the work of this laboratory:

SAMPLE FROM.	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Northern grown (1)	....	3.60	10.50	26.10	7.90	51.90
Iowa (2):						
Cut April 28, (3-6 in. high)	....	5.55	18.03	22.19	11.49	42.74
Cut May 8, (8 in. high)	....	4.14	13.58	22.74	10.67	48.87
Cut May 18, (Panicle spreading)	....	3.89	11.11	24.36	8.75	51.89
Cut May 28, (early bloom)	....	2.25	9.67	29.11	8.47	50.50
Cut June 7, (after bloom)	....	2.75	7.88	29.92	8.66	51.79
Cut July 5, in seed, brown	....	3.05	7.89	30.55	9.98	48.53
Average of 3 analyses before blooming	....	4.53	14.24	23.09	10.30	47.83
Louisiana (3)	*12.15	3.35	8.00	23.56	10.16	42.78
Mississippi (4):						
Gathered March	....	4.38	21.79	24.75	12.00	37.08
Gathered April	....	4.13	9.04	34.64	5.34	46.85
Gathered May, just headed	....	4.90	8.25	30.71	9.12	42.02
Gathered June, over ripe	....	4.13	18.21	30.12	7.45	50.09
North Dakota (5)	*15.35	3.03	6.53	27.29	4.16	43.64
Oregon (6)	*65.10	1.30	4.10	9.10	2.80	17.60

1. U. S. Dept. Agrl. Exp. Sta. Rec. 6:102. 1894.
2. Bull. Iowa Exp Sta. 11:432, 434.
3. Bull. La. Agrl. Exp. Sta. II. 19:536, 562.
4. Ann. Rept. Miss. Agrl. Exp. Sta. 8:92. 1895.
5. Bull. N. D. Agrl. Exp. Sta. 15:49. 1894.
6. Bull. Oregon Agrl. Exp. Sta. 39:49. 1895.

*Analyses are for natural or air dry condition; others are for water free substances.

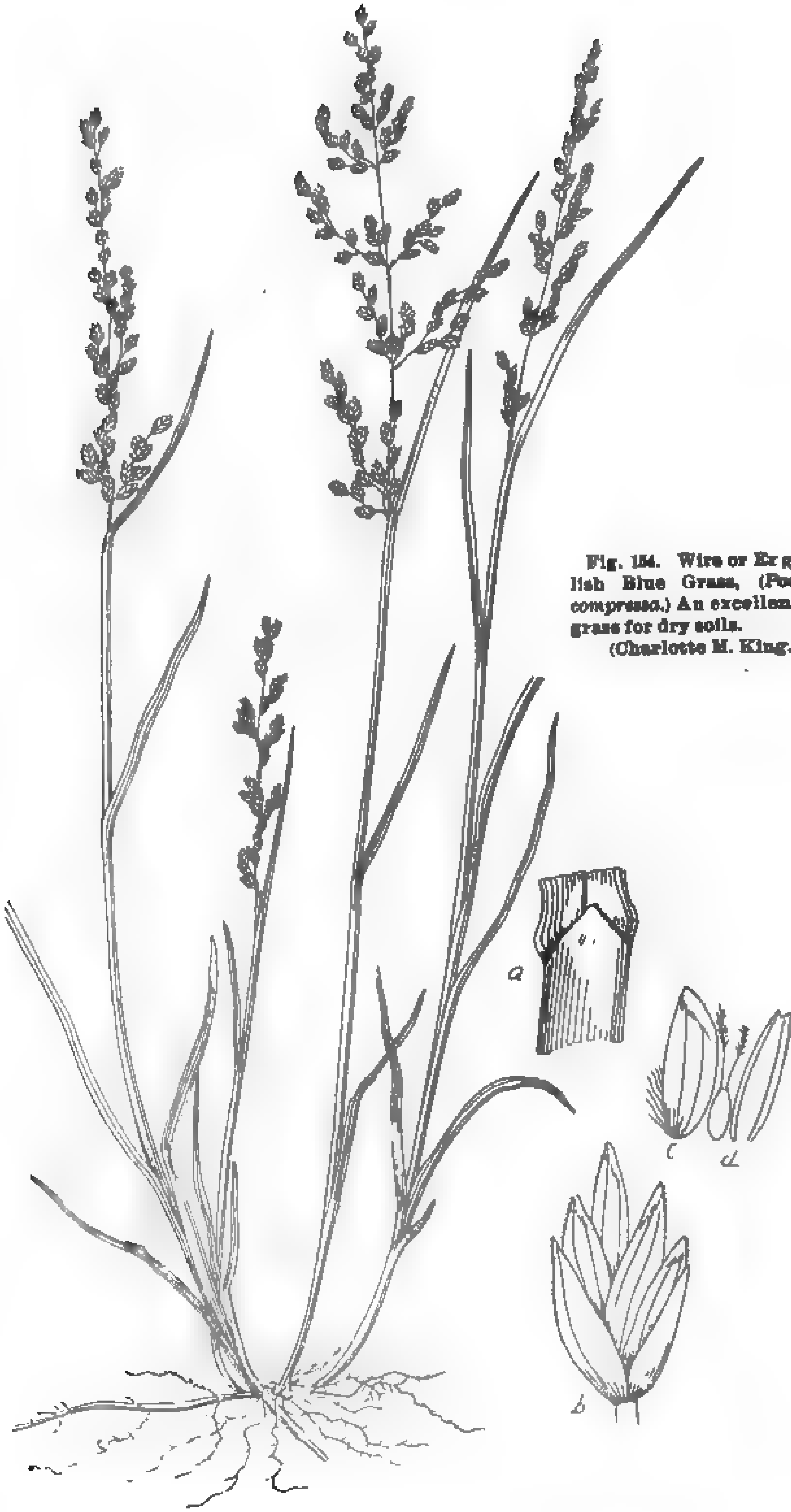


Fig. 154. Wire or English Blue Grass, (Poa compressa.) An excellent grass for dry soils.
(Charlotte M. King.)

WIRE GRASS (*Poa compressa*).—This grass is indigenous to Europe and has long been naturalized in sections of this country. It occurs in rather thin, dry pastures. Although not generally used as a pasture or forage plant in this state, in portions of New England and Canada it is used, where it is known by the name of bluegrass, a very appropriate name, as the plant has a dark bluish glaucous green color. Several agricultural writers speak in highest terms of this grass. Gould* says: "It never yields a great bulk of hay, but this bulk weighs very heavily, frequently a ton and a ton and a half to the acre where one would not expect to get one-half a ton." He considered it one of the most valuable and nutritious of grasses.

Lamson Scribner† states: "There is perhaps no better pasture grass for dry and poor soils, particularly in the eastern and middle states. It is especially valuable for dairy pastures; cows feeding on it yield the richest milk and finest butter." This is the bluegrass of New England and the middle states, and is easily distinguished from genuine bluegrass by its decidedly blue color and strongly flattened stems, lower habit of growth and smaller panicle."

CHEMICAL COMPOSITION.

There were five samples of *Poa compressa* analyzed in the station laboratory, as follows:

Sample No. 1. May 8, 1896, 8 to 9 inches high.
Sample No 2. May 22, 1896, 14 to 15 inches high.
Sample No. 3. June 3, 1896, 24 to 26 inches high.
Sample No. 4. June 11, 1896, 24 to 26 inches high.
Sample No. 5. June 23, 1896, 24 to 26 inches high.

NATURAL CONDITION.

	Water.	Fat	Protein.	Crude fiber.	Ash.	Albuminoids	Nitrogen free extract.
Sample 1	74.05	2.22	4.02	7.09	2.98	(3.33)	9.64
Sample 2	78.04	.93	3.17	7.23	2.33	(2.31)	8.30
Sample 3	73.31	.85	3.35	8.15	3.12	(2 98)	11.22
Sample 4	71.76	1.22	2.70	10.09	2.99	(2 35)	11.24
Sample 5	60.62	1.50	3.37	12.48	3.61	(2.93)	18.42

*Beal. Grasses of N. A. 1: 139. Ed. 2.
†Economic Grasses. Bull. Div. Agrost. U. S. Dept. Agrl. 14:63.

WATER FREE SUBSTANCE.

Sample 1	8.56	15.49	27.35	11.49	(12 85)	37.11
Sample 2	4.25	14 44	32.90	10.61	(10.51)	37.80
sample 3	3.18	12 55	30.56	11.68	(11.16)	42.03
Sample 4	4.30	9.54	35.75	10.58	(8 32)	39.83
Sample 5	3.82	8 56	31.69	9.18	(7.45)	46.75

The first four samples have an amount of water which varies from 71.76 to 78.04 per cent, while the fifth has only 60.62 per cent. The constituents of the grass based on the dry matter vary to a large extent. For example, the fat in the samples varies from 3.18 per cent to 8.56 per cent, while the protein gradually becomes less, from 15.49 in the sample collected May 8th, to 8.56 per cent in the sample collected June 22d. The albuminoids vary in the same way, with one exception. The crude fiber varies from 27.35 per cent in sample 1 to 35 75 per cent in sample 4. The ash constituents remain quite constant, while the amount of nitrogen free extract varies from 37.11 to 46 75 per cent. Samples 3 and 4 would represent the grass in its most favorable condition from a chemical consideration as a food. The following results have been selected for comparison with the results of this investigation:

FRESH OR AIR-DRY MATERIAL.

	Water.	Protein.	Fat.	Nitrogen free extract.	Crude Fiber.	Ash.
Tennessee (1):						
Cut May 12, 8 in. high	76.57	3.63	1.29	10.94	4.88	2.69
Cut June 3, coming in flower, 9 in. high	74.36	2.50	.77	12.78	7.36	2.23
Cut June 13, seed in milky stage, 9 in. high	69.62	2.55	.72	16.04	8.78	2.29
As hay:						
Cut before heading	9.00	30.33	5.83	28.01	16.50	10.33
Cut when heading	10.78	7.50	1.87	47.33	25.53	6.99
Cut in bloom	10.62	6.31	1.43	45.03	30.34	6.27
Seed fully formed	7.97	7.62	1.81	46.49	26.07	10.04
Cut July 1, 1891	6.27	11.65	3.32	44.27	21.98	12.51
Cut June 15, 1895	9.37	7.81	2.96	50.00	24.00	5.86

OTHER MEADOW GRASSES.

Of these the *Poa trivialis*, L., has been under cultivation longer than any other Poa. It has been tried in a limited way

1. Bull. Tenn. Agrl. Exp. Sta. 9:101-114. 1893.

in Iowa with not very great success. Sinclair* says: "The weight of hay produced from the grass of the flowering crop is much less than that which is produced from an equal weight of the seed crop. In Mr. Young's annals of agriculture we are informed, that so long ago as the year 1785, Mr. Boys, of Betshanger in Kent, a farmer of the highest reputation raised

Fig. 155. Rough stalked meadow grass (*Poa trivialis*). This is a good grass for woodland meadows. (Div. of Agrost U. S. Dept. Agrl)

at much expense, and several years' attention, from twenty to thirty bushels of the seed of this grass, which he then offered for sale at three shillings per pound. He says that it makes very fine, thick turf, and will produce a great quantity of very excellent grass from moist, rich soils. It yearly diminishes, and ultimately dies off, not infrequently in the space of four or

*Hortus Gramineus Woburnensis. 148-149.

five years. Its produce is always much greater when combined with other grasses than when cultivated by itself. With a proper admixture it will nearly double its produce, so much it delights in shelter." Stebler and Schröter* give the early history as follows: "It was cultivated in England some centuries ago. In 1681 Worlidge recommended it. He called it 'Orchiston-grass' because of its abundance in the celebrated grasslands of Orchiston, near Salisbury in Wiltshire. About the year 1785 Boys cultivated it in the county of Kent." At the present time it is in high esteem and in common cultivation, both in Britain and on the continent; in mountainous districts it always forms the staple of the natural grass.

This grass is perfectly hardy in the southern part of this state. It produces a large amount of nutritious and valuable forage. It has not, however, been tried sufficiently in central and northern Iowa to give it a general recommendation. Whereever this grass has been tried in the south, as in the Gulf states, it has been highly commended by Tracy and others. Lamson-Scribner says owing to the wooliness of the seeds they are difficult to sow, and as they are expensive this grass has not been propagated as extensively as it would have been.

Of the other American meadow grasses, more attention has been given to the Texas bluegrass (*Poa arachnifera*, Torr.) Its cultivation was first introduced by Geo. H. Hogan‡ of Texas, who recommended it very highly as a winter forage plant. Its cultivation at the Iowa experiment station began in 1888. It has also been cultivated at the Kansas§, Tennessee‖, and Mississippi¶ agricultural experiment stations. According to Lamson-Scribner it remains green throughout the year, making its chief growth during the winter months.

Professor Shelton, formerly of Kansas, states that it is a much more useful grass than blue grass for Kansas "and not unlikely one of our best grasses." Tracy says its real value for cultivation is still problematic. It endures the longest drouth without injury. Professor Mell** says: "It is now well known in most sections of the south and is becoming more and

*The Best Forage Pl. 79.

†l. c. 61.,

‡Vasey. The Agrl. Grasses and Forage Plants of the U. S. Special Bull. Dept. Agrl. 1889:64.

§Shelton. Bull. Kansas Agrl. Exp Sta. 2:22.

‖Lamson-Scribner. Grasses of Tennessee. Tenn. Agrl. Exp. Sta. 7: 110.

¶S. M. Tracy. Forage Plants. Rep. Miss. Agrl. Exp. Sta. 1892:20.

**Bull. Alabama Agrl. Exp. Sta. 100:319.

Fig. 156. Texas Blue Grass, (*Poa arachnifera*). Native to Texas, and widely recommended as a good winter pasture grass. (F. Lamson-Scribner. Div. Agrost. U. S. Dept. of Agri.)

more popular as rapidly as its fine properties are understood. The introducer of this grass, Mr. Hogan, says: "I have known it to grow ten inches in ten days during the winter." He thinks it preferable to wheat, rye or anything else grown in the winter. The writer had this grass under observation for four years here at Ames, from 1889 to 1893, and found it perfectly hardy. It is a large, vigorous, rapid growing grass and matures early in the season. It comes on again after the autumn rains and keeps green until frost Unfortunately this grass has not been tried extensively in the state, and those who desire to grow the grass should only do so in the southern half of the state, and there only in a limited way. It is best to propagate this grass by root cuttings.

Fowl meadow grass (*Poa serotina*, Ehrhart), has been tried in an experimental way at the Iowa station. It occurs as a natural grass in many sections of the state, but it is not cultivated. Flint,* in his work on grasses, makes the following

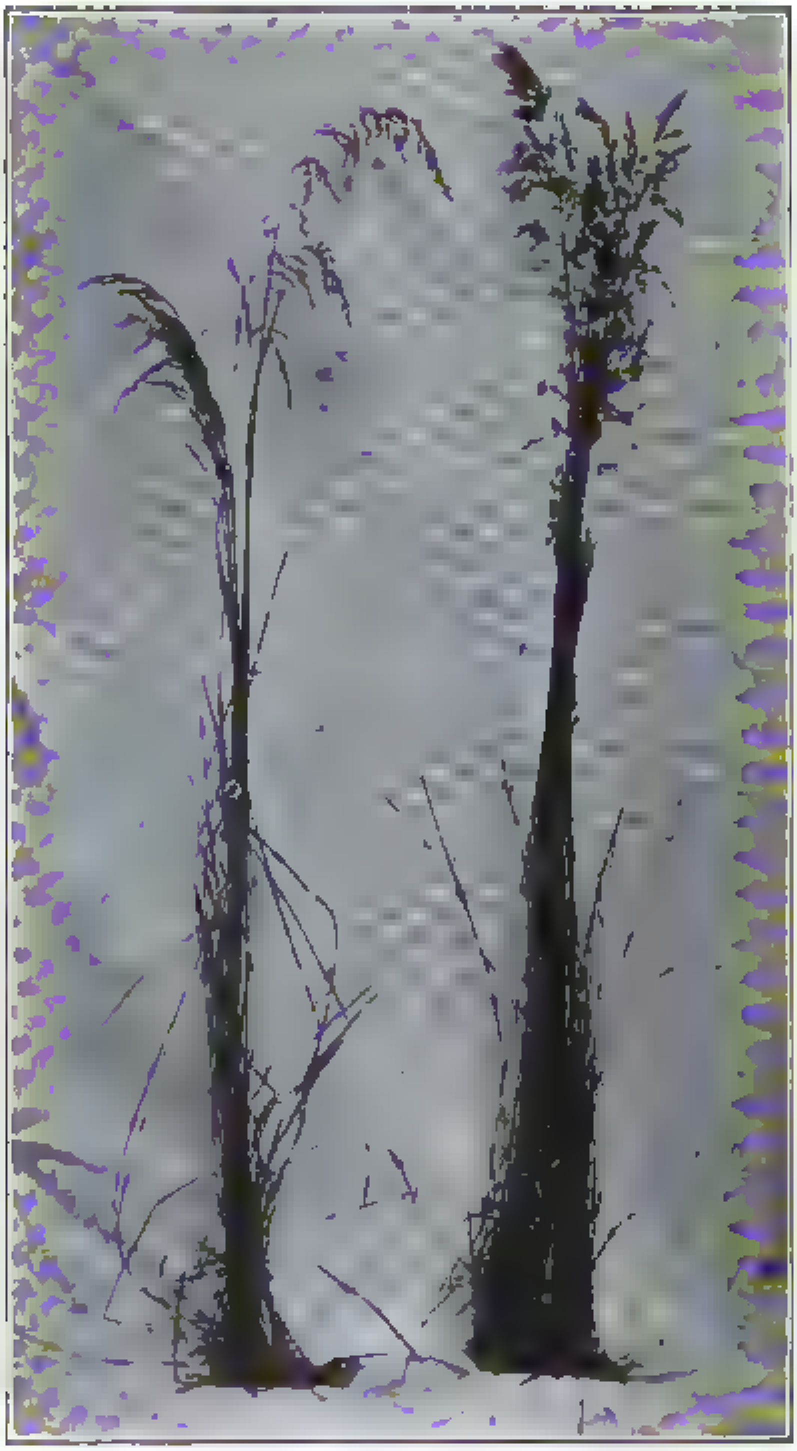


Fig. 157. Blue grass, *Poa pratensis*. The best of all our pasture grasses. Two types. Blue grass offers an excellent chance for improvement, as the cut shows.

statement: "It early commended itself to the attention of farmers, for Jared Smith, writing in 1749, says of it: 'There are two sorts of grass which are native of the country, which I would recommend. These are Herd's grass (known in Pennsylvania by the name of Timothy grass); the other is fowl

*Grasses and Forage Plants. 88.

meadow, sometimes called duck grass, and sometimes swamp wire grass.' "

This grass is seldom sown in this state, and it is only in the northern and northeastern sections of the state, where it is abundant, that it is used for forage purposes Lamson-Scribner* says it is found in nearly all parts of New England and often forms a very considerable and valued portion of the native hay of the low meadows. Professor Beal† says the stems in damp weather branch at the lower joints, and thus it is inclined to spread. On account of the large top and the slender stem this grass is rather inclined to fall over or lodge. For this reason it is frequently grown with red top, and as a matter of fact this grass is not infrequen'ly found in low meadows as a naturaliz d grass with red top.

MEADOW FOXTAIL (*Alopecurus pratensis*, L.)—Though of little value in Iowa and scarcely cultivated, it has been tried in an experimental way on the College farm for twenty years. Stebler and Schröter‡ state: "Although long ago recommended by Linnæus, its cultivation has only recently commenced." Sinclair § in 1824, wrote: "The meadow foxtail constitutes part of the produce of all the richest pastures I have examined in Lincolnshire, Devonshire, and in the vale of Aylesbury. In Mr. Westcar's celebrated pastures at Creslew I found it more prevalent than in those of Devonshire and Lincolnshire." It does not, however, appear to have been cultivated. It was early introduced into this country and has spread extensively in the eastern states. It is cultivated particularly in the middle and New England states because of its earliness.

Meadow foxtail is of little value in this state. It comes on rapidly in the spring and matures early. During the season of 1900 the culms measured two and a half feet, but they were rather sparingly produced. However, there were an abundance of leaves close to the ground. During the season of 1899, which was much more favorable, the plant was a foot taller and the flowering culms were much more numerous. It may be said further in regard to this grass that it produces no aftermath. In the east, however, this grass is considered very valuable, and in Europe one of the most valuable of the perennial grasses. Dr. Wm. J. Beal says in regard to it:

*l. c. 63.
†Grasses of N. A. 1: 140. Ed 2.
‡The Best Forage Plants. 57.
§l. c. 142.

"It bears considerable resemblance to timothy, though the culm and leaves are shorter, the spikes shorter, broader and softer; the whole plant less firm and rough, and it starts much earlier in spring, flowering three or four weeks before that well known grass.

Fig. 160. Meadow Foxtail, *Alopecurus pratensis*). A valuable grass in the east but nearly worthless in Iowa. (F. Lamson-Scribner. U. S. Dept. of Agrl.)

"Meadow foxtail is not well adapted for alternate husbandry, as it requires three or four years to become well established, but on deep, rich, moist or irrigated soils, in a cool climate not subject to drouths or very hot weather, it is a fine grass and peculiarly well adapted for permanent pasture. It makes a quick growth in spring or after feeding or mowing. It is fine, nutritious and palatable for all kinds of stock.

"Like timothy, it has no tendency to spread, as is the case with June grass, quack grass and white clover. Mr. Lawes'

experiments show that it thrives best with high manuring, supplying much nitrogen. In this respect it comes into ccmpetition with orchard grass."

CHEMICAL COMPOSITION.

One sample of this grass was analyzed in the laboratory. The sample was collected on April 30, 1896, and was 6 to 16 inches high. The analysis gave the following results:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample	80.16	.90	3 36	(2 94)	5.38	2.35	7.35

WATER FREE SUBSTANCE

Sample........................	4.56	16.93	(14.81)	27.12	11.86	39.53

The following analyses are taken for comparison with the analysis made by this station:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1, cut April 19; head just appearing (1)......................	77 10	1.08	3.60	4.17	2.11	11.94
Sample 2, cut April 19; before bloom.	76.70	1.04	3.17	5.22	1.84	12 03
Sample 3, cut May 1; in bloom.......	t0.00	1 34	4.32	9.51	3.10	21.72
Sample 4, cut May 12; after bloom...	66.60	1.17	2 88	8 47	2.73	18.15
Sample 5, time of cutting unknown..	72.63	1.16	3.12	8.66	1.71	12.72

WATER FREE SUBSTANCE.

	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1............................	4 70	15.70	18.20	9.20	52.20
Sample 2..............................	4.50	13.60	22.40	7.90	51.60
Sample 4..................................	3 40	10.80	23.80	7.80	54.20
Sample 4..................................	3 50	8.60	25.40	8.20	54.30
Sample 5................................	4 20	11.40	31.70	6.20	46.50
South Dakota (2): Cut June 1, 1892.....	3.31	9.91	34.56	10.54	41.69

1. U. S. Dept. Agrl. Office Exp. Sta. Bull. 11:31. 1892.
2. Bull. S. D. Agrl. Exp. Sta. 40:70. 1894.

BROME GRASSES.

Among the brome grasses there are several important forage plants. Much attention has recently been given to Hungarian brome or awnless brome grass (*Bromus inermis*, Leyss). Stebler and Schröter*, writing in 1882, state: "This

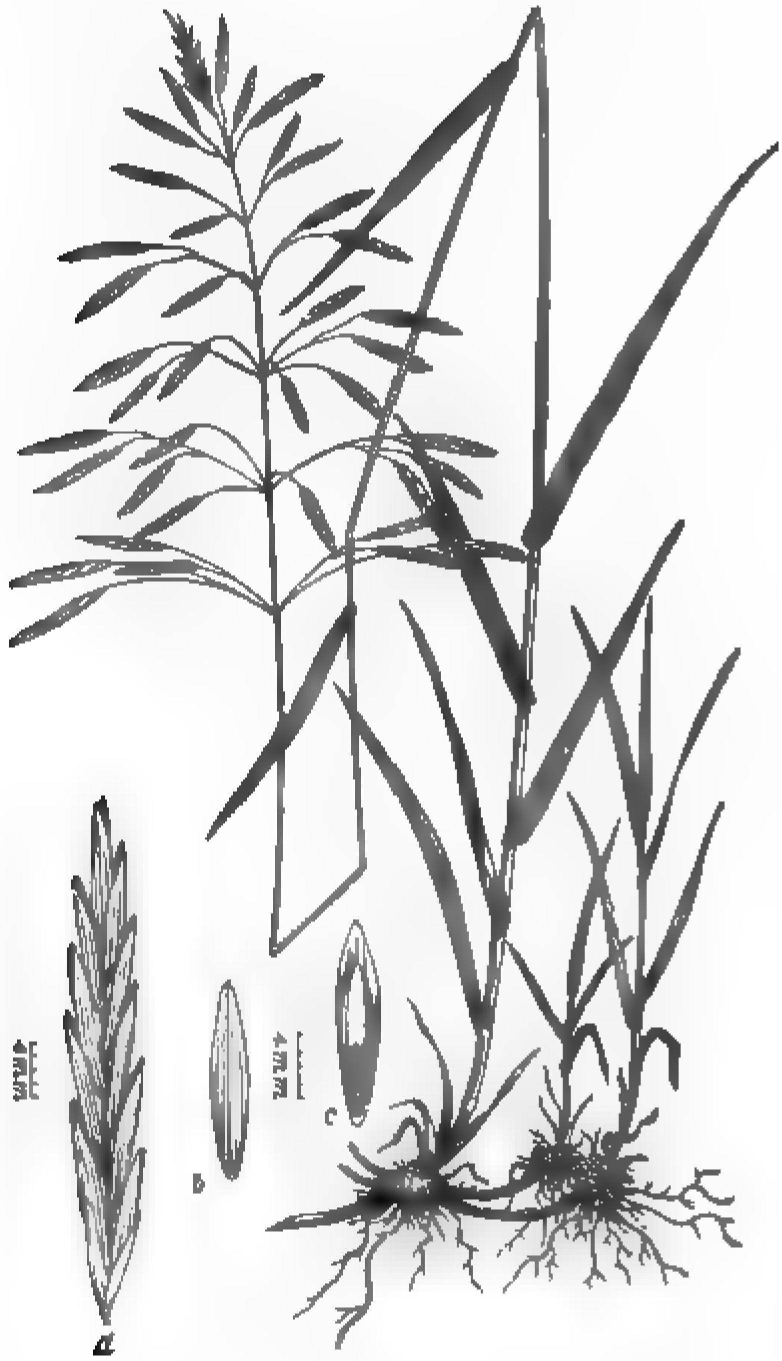


Fig. 150. Hungarian Brome Grass, (*Bromus inermis*). The best of all the recently introduced grasses. May be used in meadow and pasture. (Div. of Agrost. U. S. Dept. of Agri.)

must be a good fodder grass, especially for sheep, because it grows in the cattle-rearing districts of Aschersleben, renowned for its exceedingly tender mutton. Awnless brome grass has only quite recently come into cultivation, more particularly in Hungary." Its further history is given by Lamson-Scribner.†

*l. c. 115.

†Economic grasses. Bull. U. S. Dept. of Agr. Div. of Agrost. 14:23.

It was introduced by the California agricultural experiment station about 1880. Its cultivation on the college grounds began in 1888. It has been grown since 1890 at Dysart and Battle Creek. Since 1897 it has become more widely diffused in the state and elsewhere largely through the efforts of the Secretary of Agriculture, Hon. James Wilson, the agricultural press and F. Lamson-Scribner. Seedsmen also have done much to extend its cultivation.

Hungarian brome (*Bromus inermis*) is without doubt one of the most valuable of all the grasses which have been introduced in recent years. Not only is it an excellent drouth resister but it is a most productive grass. It starts early in spring and affords good picking nearly as early as blue grass. For pasture purposes it is certainly far better than timothy. It is only a question of time until this grass will become as common as timothy. There has never been a crop failure of this since its growth on the college farm, but there is considerable variation with reference to its productiveness. Newly sown meadows are much more productive than those that are two or three years old. During the season of 1900 this grass was quite vigorous, the culms measuring from two to three feet high. There was an even mat, but in meadows three years old it was somewhat dwarfed, and this seems to be the usual experience with this grass. During 1899 this grass did very much better. Prof. James Atkinson* says in regard to it:

"Owing to its extreme hardiness it is one of the first plants to begin to grow in the spring, when once established. In case of a one-year-old sod, it began to head out six weeks after growth began in the spring. The same crop was cut and gave a yield of twelve tons of green fodder June 10th, which cured into five tons of hay. It must be remembered that the soil upon which this was grown was very rich. A bare soil, treated in the same manner, produced less than one ton per acre. According to station analysis, it is quite similar to timothy in composition. If seeded thickly and cut at the proper time, it is a little superior, owing to the leafy nature of its growth. At cutting time, the leaves were stripped off of a portion of the crop, and it was found that there was a greater percentage of leaves than of stem. It yields at the rate of two or three tons to the acre."

*Bull. Iowa Agr. Col. Exp. Sta. 45:225.

Shepard and Williams* state that it has endured drouth perfectly in South Dakota, and has never winter killed in the least. Lamson-Scribner† says: "The strong perennial character of this brome grass and its unusual drouth resisting powers are qualities which recommend it for general cultivation, particularly in the semi-arid regions of the west and northwest. Its nutritive value is comparatively low, and before undertaking its cultivation the fact should be remembered that it is somewhat difficult to eradicate when once established, although by no means so difficult as couch grass or Johnson grass." In Iowa there has been no difficulty of clearing a field. Mr. S. A. Bedford‡ states that as a pasture grass for Manitoba it is perhaps unequaled. It comes on early and continues green until snow covers the ground.

P. Beveridge Kennedy§ says in regard to this grass: "In a few years it forms a very tough sod, soon crowding out other grasses, clovers, and weeds. Its remarkable drought resisting qualities have proved it to be a most valuable grass for dry regions where other grasses could hardly exist. It is the most suitable grass yet introduced for the dry regions of the west and northwest. As it is thoroughly permanent and grows with wonderful rapidity, producing heavy crops of hay and luxuriant pasturage, its value to the farmers of the semi-arid regions of this country cannot be overestimated. All kinds of stock eat it with relish, and the chemical analyses made show that it is rich in flesh-forming materials, much more so than timothy. It is very hardy, and not injured by severe spring and fall frosts when once establisned. As it starts to grow very early in the spring, before any of the grasses upon the native prairies show any signs of life, and remains green and succulent far into November, it will supply the long-felt want of early and late fall pastures."

CHEMICAL COMPOSITION.

Of this brome grass the following samples were analyzed:

Sample 1. April 30, 1896, 6 to 12 inches high.
Sample 2. June 3, 1896, 38 to 40 inches high.
Sample 3. June 15, 1896, 41 to 42 inches high.

*Bull. South Dak. Agrl. Exp. Sta. 40:144.
†Bull. U S. Dept. Agrl. 14:23.
‡Rep. Exp. Farms Canada 1896:337.
§Bull. U. S. Dept. Agric. Div. Agrost. 22.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	79.97	1.05	3.21	(3.04)	4.53	2 33	8.91
Sample 2	73.55	.53	3.73	(3.15)	9.65	2.33	10.21
Sample 3	67.66	1.04	3.93	(2.48)	11.96	3 45	11.93

WATER FREE SUBSTANCE.

Sample 1	5.26	16 06	(15.19)	22.62	11.64	44.42
Sample 2	2.00	14 10	(11.54)	36 49	8 82	38.59
Sample 3	3.20	12 26	(7.69)	36 98	10.66	36.90

In the consideration of the above samples we find that the amount of water decreases from 79.97 per cent to 67.66 per cent, and it is a regular decrease as the plant becomes older. In the water free substance we find, however, that the percentage of fat varies from 5.26 per cent to 2.00 per cent, and the change is an irregular one. The protein varies from 16.06 to 12.26 per cent, decreasing as the growth of the plant increases, but it will be noticed that the sample 38 to 40 inches high has only 1.96 per cent less of protein than the sample 6 to 12 inches high. The difference between the albuminoids is greater than that of the protein, that is 15.19 to 7.69 per cent, and in the samples 2 and 3, while there is only a difference in height of 2 or 3 inches, yet the difference in the amount of albuminoids present is 3.85 per cent in favor of the second sample. The crude fiber is naturally much less in the young sample, while the two latter samples have nearly the same amount present. The first sample of the grass has the largest amount of nitrogen free extract, and this decreases as the plant becomes older, while the amount of the ash varies without regard to the growth of the plant.

The following analyses have been selected for comparison with the analyses here:

WATER FREE SUBSTANCE.

	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
U. S. Dept. Agrl. (1): Aver. of 2 samples..	4.91	11.86	32.11	8.62	39.50
Iowa (2):					
Cut June 21, just past bloom, height 36–42 in.....	1.60	11.92	34.51	10.20	41.77
Cut May 8, height 16 in	5.66	26.27	21.65	11.02	35 40
Cut May 18, height 20 in	3.71	21.12	24 50	11.03	39 64
Cut May 23..........................	2 61	17.63	29 11	10.08	40.57
Cut June 7, early bloom................	2.43	12 45	32.33	9.77	43.02
South Dakota (3): Cut July 7, 1892......	2.06	10 79	41.27	8.08	37.80
Mississippi (4):					
Cut June..............................	3.79	8.18	33.79	6 66	47.58
Cut August............................	6 04	21.53	30 44	10 57	31.42

SHORT AWNED BROME GRASS (*Bromus marginatus*, Nees).—The culture of the short awned brome grass was introduced in Iowa by R. P. Speer* in 1889, who obtained the seed from Montana, collected by Prof. J. Craig, who was sent there to make a collection of the most worthy and valuable grasses growing in the west. It was cultivated on the college grounds for a few years and merits more extensive cultivation. It was distributed to a limited extent to Iowa farmers, but it has not been cultivated extensively in any part of the country. It gives promise of being as valuable as the Hungarian brome. It is perfectly hardy, resists drouth well and is capable of producing from two to three tons of hay to the acre in ordinary seasons. The aftermath is also excellent. The grass has become partially established in this state, both at Dysart and the Iowa Agricultural College, and we commend it for trial in this state. It is equal to the Hungarian brome grass on the college grounds. In the season of 1900 it measured from three to four feet. This is what Dr. Kennedy† says in regard to it:

1. U. S. Dept. Agrl. Exp. Sta. Rec. 6:101. 1894.
2. Bull. Iowa Agrl. Exp. Sta. 11:466, 475. 1888.
3. Bull. S. D. Agrl. Exp. Sta. 40:144. 1894.
4. Ann. Rept. Miss. Agrl. Exp. Sta. 8:90. 1895.

*Bull. Iowa Agrl. Exp. Sta. 11: 1890. 446.
†Bull. U. S Dept. Agrl. Div. Agros. 22:62.

Fig. 160A. Short-awned Brome Grass (*Bromus marginatus*). A valuable western grass. a, empty glumes, with three florets. b, dorsal view of flowering glume. (Shear. Div. Agrost. U. S. Dept. of Agrl.)

"An erect, robust native grass, two to four feet high, with numerous large leaves and long, closely appressed branches to the panicle. In Wyoming and Montana it occurs in the open woods among the mountains, where it sometimes forms meadow-like tracts of considerable extent at an altitude of from 5,000 to 8,000 feet. It has been introduced and grown for a number of years in central and western Iowa, where, under favorable conditions, two crops may be cut in a single season. In Colorado it is found to be valuable in the native meadows at an altitude of from 6,000 to 9,500 feet. Short awned brome grass produces an abundance of leaves, which are well liked by stock. Although not so valuable as the smooth brome grass, yet it is

worthy of being extensively tried, especially in meadows at high altitudes. Its cultivation has been carried on to some extent in the northwest, with very promising results."

The results of the analysis of the two samples of this grass are given below:

Sample No. 1. Gathered April 27, 1896, height 12 inches.
Sample No. 2. Gathered May 19, 1896, height 14 to 20 inches.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1..............	82.30	1.56	4.71	(3 41)	4.80	2.59	4 04
Sample 2..............	80.48	1 21	4 23	(3.28)	5.18	2.40	6.50

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1..	8.82	26.63	(19.28)	27.09	14.66	23.80
Sample 2......................	6.22	21.69	(16.84)	26.56	12.33	33.20

The water content of the two samples are very close, less than 2 per cent, and on making a comparison of the various constituents of the dry matter, it is found that as a result of the difference of twenty-two days sample 2 has 2.60 per cent less of fat and 4.97 per cent less of protein. The same condition is present in the amount of albuminoids, where there is a difference of 2.44 per cent of albuminoids in favor of sample 1. The amounts of crude fiber in both samples are very close, but the difference of nitrogen free extract is 9.40 per cent in favor of the sample which was collected last. The amount of ash is largest in sample 1.

For comparison the following analyses are added:

	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Iowa (1):						
Cut June 9, beginning to bloom, height 30 in..................	68.85	.66	4.32	9.88	3.04	13.25
Cut April 29, height 12 inches...	*77.24	6.26	26.64	20.31	13.50	33 29
Cut May 10, height 15 inches....	*75 00	5.32	22.53	23.84	12.83	35.49
Cut May 20, height 20 inches....	*76.78	3.58	18.83	21.58	12.18	43.83
Cut May 30, panicle spreading...	*72 17	2.12	16.00	32.26	10 64	38.98
Cut June 9, early bloom.........	*68.85	2.12	13.88	31.71	9.76	42.53
Cut June 20, seed forming.......	*66.29	2.25	11.88	30.38	9 25	46.24

OTHER BROME GRASSES.—Soft chess (*Bromus hordeaceus*, L.) has been introduced at various points in the state for forage purposes. Some years ago R. P. Speer introduced it on the college farm, but soon found that it was an entirely worthless grass. Since then it has been common on the college farm. It comes on early and makes a good growth. Its weedy character should prevent farmers from sowing any more of it.

In regard to *Bromus hordeaceus* Prof. F. Lamson-Scribner† says:

"An erect annual, one to three feet high, having the sheaths, leaves and spikelets of the erect panicle softly pubescent. It has a marked resemblance to cheat, from which it differs in its more erect panicle and hairiness. It is a native of Europe, but has become widely disseminated in this country, although less common than cheat and smooth brome grass, but like these can only be regarded as a weed. It has, however, been recommended for cultivation on thin, sandy land where better grasses will not succeed."

CHEMICAL COMPOSITION.

Five samples of *Bromus hordeaceus* were analyzed in the experiment station laboratory with the following results:

1. Bull. Iowa Agrl. Exp. Sta. 11:465, 474.

*Percentages of water are given for the original sample and all other percentages are for water free substance.

†Bull. Div. Agrostology. U. S. Dept. Agrl. 3:31.

Fig. 160

Fig. 161

Fig. 160. Soft chess, (*Bromus hordeaceus*). A grass extensively naturalized in portions of this state, but of little value as a forage plant. a, empty glumes; b, flowering glume; c, palea. (Div. Agrost. U. S. Dept. Agri.)

Fig. 161. Common chess, (*Bromus secalinus*). Widely distributed annual, frequently occurring in wheat fields; but of little value as a forage plant in this state (Div. Agrost. U. S. Dept. Agri.)

Sample 1. Collected April 24, 1896, 5 to 10 inches high.

Sample 2. Collected May 4, 1896, 12 to 18 inches high, no heads.

Sample 3. Collected May 11, 1896, 18 to 24 inches high, just beginning to head out.

Sample 4. Collected May 20, 1896.

Sample 5. Collected June 1, 1896, 30 to 32 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Album'noids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	85 07	1.41	4 19	(3.23)	3 18	1.92	4.23
Sample 2	87 29	.94	2.14	(1.88)	3.38	1.83	4.45
Sample 3	79.37	.85	2 62	(2.50)	5.47	2 19	9.50
Sample 4	80.63	.78	2.96	(2.10)	6.42	2.05	7.16
Sample 5	71.41	.85	3.52	(3.08)	10.01	2 54	11 67

WATER FREE SUBSTANCE.

	Fat.	Protein.	Album'noids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	9 46	28.05	(21.61)	21.31	12.89	28.26
Sample 2	7.43	16.83	(14 80)	26.61	14 38	34.75
Sample 3	4.10	12 71	(12.12)	26.54	10.64	46.01
Sample 4	4.08	15.30	(10.88)	33.18	10.61	36 83
Sample 5	2.95	12 30	(10.76)	35.01	8.91	40.83

Considering the five analyses of *Bromus hordeaceus* we find that the water content in the samples in their natural condition varies from 71.41 per cent to 87.29 per cent, and the amount of water varies irregularly in the samples In the dry matter or water free substance, we find that the fat varies from 9 46 per cent to 2.95 per cent, decreasing as the grass becomes older. The crude protein varies from 28,05 per cent to 12.30 per cent, and with one exception the amount decreases as the plant grows older. The amount of albuminoids, however, varies from 21.61 per cent to 10.76 per cent, and these decrease in amount regularly as the grasses increase in growth. The crude fiber varies from 26.54 per cent to 35.01 per cent, and is irregular in the amount present and tends to increase as the plant increases in age. The nitrogen free extract, however, is very irregular in the amount present. The ash, on the contrary, tends to decrease with the age of the grass.

One other sample is added for comparison with the results of the laboratory:

WATER FREE EXTRACT.

	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Mississippi, collected June (1)...........	4.08	10.05	34.02	6.72	45.13

Chess or cheat (*Bromus secalinus*, L.) is also quite common in many parts of the state, and although more valuable than *Bromus hordeaceus*, must be regarded as a weed.

Chess or cheat is a well known weedy annual grass introduced in this country a number of years ago, and pretty generally occurring in the state where wheat is grown. It has a loose, spreading panicle. The awns of the flowering glumes are quite variable. This plant is a weed, but not quite so injurious as *Bromus hordeaceus*, as it has some redeeming features as a forage plant. Professor Tracy speaks favorably of this grass for the southern states. Chess or cheat is believed by many people to be a degenerated wheat, but this is not true. Cheat can only produce cheat, and where these plants occur it is certain that they were from cheat sown with the wheat, or that the seeds were scattered by birds or animals. Prof. F. Lamson-Scribner* says: "Cheat and wheat are only remotely related; they belong to quite distinct tribes in the grass family, and wheat is less likely to change into cheat in a single generation than the more nearly allied oats, or than wheat is to change into barley, with which it is very closely related."

CHEMICAL COMPOSITION.

The following samples of *Bromus secalinus* were analyzed in the laboratory at this station:

Sample 1. May 20, 1896, height 25 to 30 inches.
Sample 2. June 15, 1896, height 28 to 29 inches.

1. U. S. Dept. Agrl. Exp. Sta. Rec. 6: 101. 1894.
*Bull. Div. Agros. U. S. Dept. Agrl. 3: 32.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	79.22	1.99	2.74	(1.96)	9 15	2.21	4.59
Sample 2	66.55	1.19	3.23	(2.49)	12.38	2 64	14.01

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	9.59	13.17	(9.42)	44.04	10.63	22.57
Sample 2	3 57	9.66	(7 44)	37.03	7 91	41.83

In considering the composition of *Bromus secalinus* we find that the sample collected in May has nearly 13 per cent more water than that of the June sample, both of the samples being practically the same size. In considering the constituents of the dry matter, the first sample has 6.02 per cent more fat than the second, and it has also 3.51 per cent more of protein and 1.98 per cent more of albuminoids. The crude fiber is present to the extent of 7.01 per cent over the amount in the second sample. As regards the amount of nitrogen free extract, there is 18.26 per cent less in the early than in the late sample. The ash constituents are 2.72 per cent less in the second than in the first.

For comparison with the work done here, we have selected the following analyses:

IN FRESH OR AIR-DRY MATERIAL.

	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
New York (1)	60.35	1.12	3.17	13.05	1.85	20.46
*Mississippi (2)	58.54	......	......	......	......	.....
Oregon (3)	8.56	1.75	3.61	31.90	9.19	44.99

*Dry analysis of other materials given below under the same heading.

Fig. 163. *Bromus tectorum.* A nearly worthless annual found here and there in the state. (F. Lamson-Scribner. Div. Agrost. U. S. Dept. of Agri.)

WATER FREE SUBSTANCE.

	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
New York (1)	2.80	8 00	32.90	4.70	51.60
Mississippi (2):					
Gathered in June	2.59	5 18	29.30	5.61	57.32

1. U. S. Dept. Agri. Exp. Sta. Bull. 11: 39.
2. Ann. Rept. Mississippi Agri. Exp. Sta. 8: 90. 1895.
3. Bull. Oregon Agri. Exp. Sta. 39: 44. 1895.

Fig. 163. Woodland Chess, (*Bromus ciliatus*). Quite widely distributed in timber, and of considerable value as a forage plant. (Charlotte M. King).

The *Bromus racemosus*, L., allied to *B. secalinus*, is sometimes cultivated in the south. This is an introduced annual, one to three feet high, with a more or less spreading panicle with smooth spikelets. A very common grass in cultivated fields and waste places. It has been recommended for some sections of our country, but like the other two species is of very little value.

Bromus tectorum, L., is another worthless immigrant which has made its appearance at several points in waste places about cities. This is a tufted annual, from one to two feet high, erect or somewhat geniculate at the base. This species is of little value for forage purposes. For forage purposes it is not as good as *Bromus hordeaceus.*

The woodland chess (*Bromus ciliatus*, L.) makes a vigorous growth early in the season. Though never abundant in one place, it is widely scattered in timber and affords excellent forage in the timber lot.

CHEMICAL COMPOSITION.

The South Dakota (1) station analyzed one sample of the grass, with the following results:

	Air dry substance.	Water free substance.
Water	8.73	......
Ash	8.00	8.77
Ether extract	3 00	3.29
Crude fiber	30.75	33.69
Crude protein	7.75	8.49
Nitrogen free extract	41.77	45.76
Total	100.00	100.00

Bromus purgans, L.—This is taller and stouter than *B. ciliatus*, a perennial, from two to three and a half feet high. Culm is erect and smooth, with somewhat drooping panicles. This species is common in moist meadows, in some cases covering considerable area. The form most common in Iowa is the *Bromus purgans latiglumis*, which is indeed a most excellent grass in moist meadows in north central Iowa. In chemical composition this compares with *Bromus ciliatus.*

Schrader's Brome grass (*B. unioloides*, Willd.), a native of South America, has not been cultivated in Iowa, though no doubt would succeed, as it is hardy in northern Colorado. It is one of the valuable winter grasses of the south.

This species was described and figured by Willdenow in 1806 from specimens growing in the botanical garden at Berlin, the seed originally coming from South Carolina, but the grass is

1 South Dak. Bull. 40. 143.

Fig. 184. Swamp Chess. (*Bromus purgans latiglumis*.) A tall, fine grass for low meadows. (Charlotte M. King.)

native to South America and was evidently early introduced into the Carolinas. Mr. Shear says it also appears to be native in Central America and Mexico, and possibly Texas. Its cultivation was first introduced by Iverson, of South Carolina, in 1853 or 1854. This grass is not adapted to our conditions in this state, but for the southern states it is an admirable grass. Mr. C. L. Shear* says:

"The grass is naturally an annual, producing its seed and then dying, but if prevented from seeding by continuous cutting or pasturing, it will survive several years and produce well; but as the grass dries up during the summer, the use of the land during that period is practically lost. Results giving the most general satisfaction in growing this grass may be secured by pasturing it until spring and then letting it reseed itself. After it has matured its seed, the land may be plowed and sown, preferably to cow peas or Japan clover, which should be harvested in time to allow the rescue grass to start again with the first autumnal rains. Excellent volunteer crops may be secured in this way for several years."

CHEMICAL COMPOSITION.

The analysis by the South Dakota Experiment Station (1) gave the following results:

	Air dry substance.	Water free substance.
Water	7.13	......
Ash	9.03	9 72
Ether extract	2.09	2.25
Crude fiber	32.39	34.88
Crude protein	9 97	10.74
Nitrogen free extract	39.39	42.41
Total	100.00	100.00

The United States Department of Agriculture (2) analyzed a number of samples of this grass, with the following results:

Sample No. 1. Cut April 23d.
Sample No. 2. Cut May 4th.
Sample No. 3. Cut May 13th.
Sample No. 4. Cut June 1st.
Sample No. 5. Cut June 1st, in seed.

*U. S. Dept. Agrl. Div. Agros. 23:51.
1 Bull. South Dakota Agr. Exp. Sta. 40: 146.
2 Bull. U. S. Dept. of Agrl. Off. Exp. Sta. 11: 82.

NATURAL CONDITION.

	Water.	Ash.	Protein.	Crude fiber.	Nitrogen free extract.	Fat.
Sample No. 1	80.60	2.07	3.31	3.60	9.45	.97
Sample No. 2	75.40	2.20	3 53	5.47	12.55	.85
Sample No. 3	79.40	1.91	2.60	4 67	10.60	.82
Sample No. 4	67 50	2.17	3.52	8 23	17.81	.77
Sample No. 5	64.70	3.02	3.45	7.01	21.08	.74

WATER FREE SUBSTANCE.

	Ash.	Protein.	Crude fiber.	Nitrogen free extract.	Fat.
Sample No. 1	10.70	17.10	18.60	48 60	5.00
Sample No. 2	8.90	14 30	22.20	51.10	3.50
Sample No. 3	9.30	12.60	22.70	51.40	4.00
Sample No. 4	6.70	10.80	25.30	54.80	2.40
Sample No. 5	8.60	9.80	19.90	59.60	2.10

REDTOP (*Agrostis alba*), L.—Many writers of the early part of this century do not speak favorably of *Agrostis alba* as a forage plant, although its cultivation began in 1761. Stebler and Schröter* state that it was introduced into Ireland about the beginning of this century; Dr. Richardson pointed out its merit, and on his recommendation it came to be extensively cultivated in Great Britain. The cultivation of Fiorin commenced on the continent about 1840, where it was held in high esteem. Jessen†, 1863, praises its qualities as a forage plant in Germany, but says it is difficult to harvest. In this country it has been cultivated for a long time. Flint‡ says: "It was called simply English grass by Eliot, Dean and other early writers, and by the English, fine bent. Most of the grasses of this genus are known in England under the name of 'Bent Grass,' of which there are many species."

Redtop is a very variable species; there are included under it a number of well marked and distinct varieties, some of which have received distinct names.

Prof. F. Lamson-Scribner,§ in his "Grasses of Tennessee," makes the following statement with reference to the different forms:

"*Agrostis vulgaris*, With. Fine Bent, is now united with *A. alba*, L., not being regarded as botanically distinct. *A. vulgaris*,

*l. c. 66.
†Deutschland's Gräser. 63.
‡l. c. 40-41.
§Bull. Univ. Tennessee Agrl. Exp. Sta. 7: 1.78.

Fig. 165. Red Top, (*Agrostis alba*). A fine grass for low meadows. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

however, is a good agricultural form quite distinct from *A. alba*. *Agrostis stolonifera* is also classed as only a variety of *A. alba*. Trinius referred these, and also some others which have been classed as species, to *Agrostis polymorpha*, Huds."

The forms we have may be separated as follows:

Ligule, 1 to 4 lines long, usually ribbed toward the base. Panicle open, culms erect or geniculate at the lower joints..... ....*A. alba*

Panicle contracted linear, culms extensively creeping or stoloniferous ....*A. stolonifera*

Ligule less than a line long, sometimes nearly obsolete; panicle branches spreading, smooth............. ....*A. vulgaris*

This plant produces culms from one to two feet high, ascending smooth from a creeping rootstock. Leaves short and flat

with a contracted or oblong panicle and producing few or many small branches in a whorl. Grass starts rather late in the spring but affords very good pasture during the entire summer, especially in wet soils. It yields from one to two tons of hay to the acre which is of excellent quality.

Prof. F. Lamson-Scribner* says:

"Herd's grass or redtop has long been known to our farmers, and in its several forms is deemed valuable for permanent meadows and pastures, where the land is not too dry. On good soil it yields well and makes excellent hay. Some of the forms employed alone, make, under favorable circumstances, the softest and finest turfs for lawns."

CHEMICAL COMPOSITION.

One sample of this grass was analyzed by the South Dakota station (1).

	Air dry substance.	Water free substance.
Water	7.85	......
Ash	9 03	9.80
Ether extract	2.39	2.59
Crude fiber	29.19	31.68
Crude protein	11.93	12.95
Nitrogen free extract	39.61	42.98
Total	100.00	100.00

Professor Beal† says:

"Redtop in this country is often sown on marshes too wet for some of the better grasses. It is not well adapted to alternate husbandry, as it takes several years to become well established."

Also, F. Lamson-Scribner‡ says:

"It makes a very resistant and leafy turf, which well withstands the tramping of stock. It grows well, also, as far south as Tennessee. Among the forms of low growth are two varieties which are unsurpassed, either in fineness or richness of color, for making lawns."

*Bull. Univ. Tennessee Agrl. Exp. Sta. 7: 1: 79.

(1) South Dakota Bull., No. 40: 82.

†Grasses of North America. 1:145.

‡Bull. Div. Agros. U. S. Dept. Agrl. 3:13.

Fig. 168. Thin-grass. (*Agrostis perennans*). Widely distributed in timber. Not especially valuable for forage purposes. (F. Lamson-Scribner, U. S. Dept. Agrl.)

Redtop is a valuable grass, particularly in low meadows, where it is common. It makes a fine turf and may be pastured without injury. The hay is of the finest quality. Although this grass is naturalized in many parts of the state, it is seldom sown.

Other species.—Several other species of Agrostis are used for meadow and pasture purposes. The most valuable of these are Rhode Island Bent (*A. canina*, L.) and the rough-leaved Bent (*A. asperifolia*, Trin.), a native of the Rocky mountain regions. We also have several native species in Iowa, like the *Agrostis perennans*, which occurs in woodland, and is common in moist, shady places. Though widely distributed, this species

is of little value for forage purposes, as it produces so scantily. Another species, *A. scabra*, is a widely distributed grass, usually occurring in rather light soils. Aside from the fact that it may be used for ornamental purposes, it produces some little forage, though it cannot be considered of any value for this purpose.

THE TALL MEADOW OAT GRASS (*Arrhenatherum avenaceum*, Beauv.), has been cultivated for a considerable length of time. Sinclair,* in 1824, does not seem to have been highly impressed

Fig. 167. Tall Meadow-oat grass, (*Arrhenathum avenaceum*). A valuable European grass. Although perfectly hardy, and adapted to Iowa conditions, it has not given general satisfaction. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

with the grass. It does not, according to this writer, do well when sown by itself. He also made experiments, sowing it at different times, and concludes that May is the best month. Sowerby and Johnson† seem not to have been favorably

*Hortus Gramineus Woburnensis. 161.

†The Grasses of Great Britian. 55. London.

impressed with it as a cultivated grass. Its further early history is given by Stebler and Schröter* as follows: "Towards the beginning of the last century, false oat grass was cultivated in Dauphiny, in the neighborhood of Geneva, and here and there in Canton Berne. Stapfer, in a memoir presented to the Agricultural Society of Berne in 1762, strongly recommended its cultivation. In 1790, Judtmann advocated its use for mixing with red clover, sanfoin, and lucerne. Later it became much over-estimated, *e. g.*, by Mauke, Hansen and Hannemann. The French, as Schwerz says, 'elated it to the skies.' Soon, however, it became as much depreciated as it had formerly been over-estimated; Hector in his work on grasses does not even mention it."

European authorities differ in regard to its value. Sir J. B. Lawes states it is of questionable value in England. Mr. Gorrie states that it yields continuously from early spring until winter frosts. It has a very disagreeable, bitter taste, which causes it to be avoided by horses, cattle and sheep. It is much subject to rust and smut. Professor Buckman† thinks it is not advisable to encourage its cultivation. The opinions in this country differ in regard to its usefulness. Beal‡ states that it is suited for alternate husbandry and for dry countries. It is common in California and greatly esteemed there. He says in regard to it: "The writer has raised this grass on rather light, sandy soil at Lansing, Mich., for twenty years or more, has seen it in some other localities in the state, and thinks he can tell why there are such conflicting opinions in relation to its value. In England the climate is moist, and the finer succulent grasses thrive well, while tall oat grass does better in a hotter, dryer climate. As it blossoms rather early, many let it go too long before cutting, when the stems become hard and of poor quality. Again, bad weather often interferes with the cutting at just the right time, and poor hay is the result. A man doesn't want a very large quantity of this grass to mow, unless he is prepared to cut it all in a day or two. It makes a fine growth the first season after sowing, and if sown alone will cut a good crop of hay."

Flint§ notes its early cultivation in New England, where at one time it was highly esteemed. It has been tried in Iowa

*Best Grasses. 39.
†Beal. Grasses of N. Am. 1: 122 2 Ed.
‡Beal. Grasses of N. America. 1: 125.
§Grasses and Forage Plants. 129. 2 Ed.

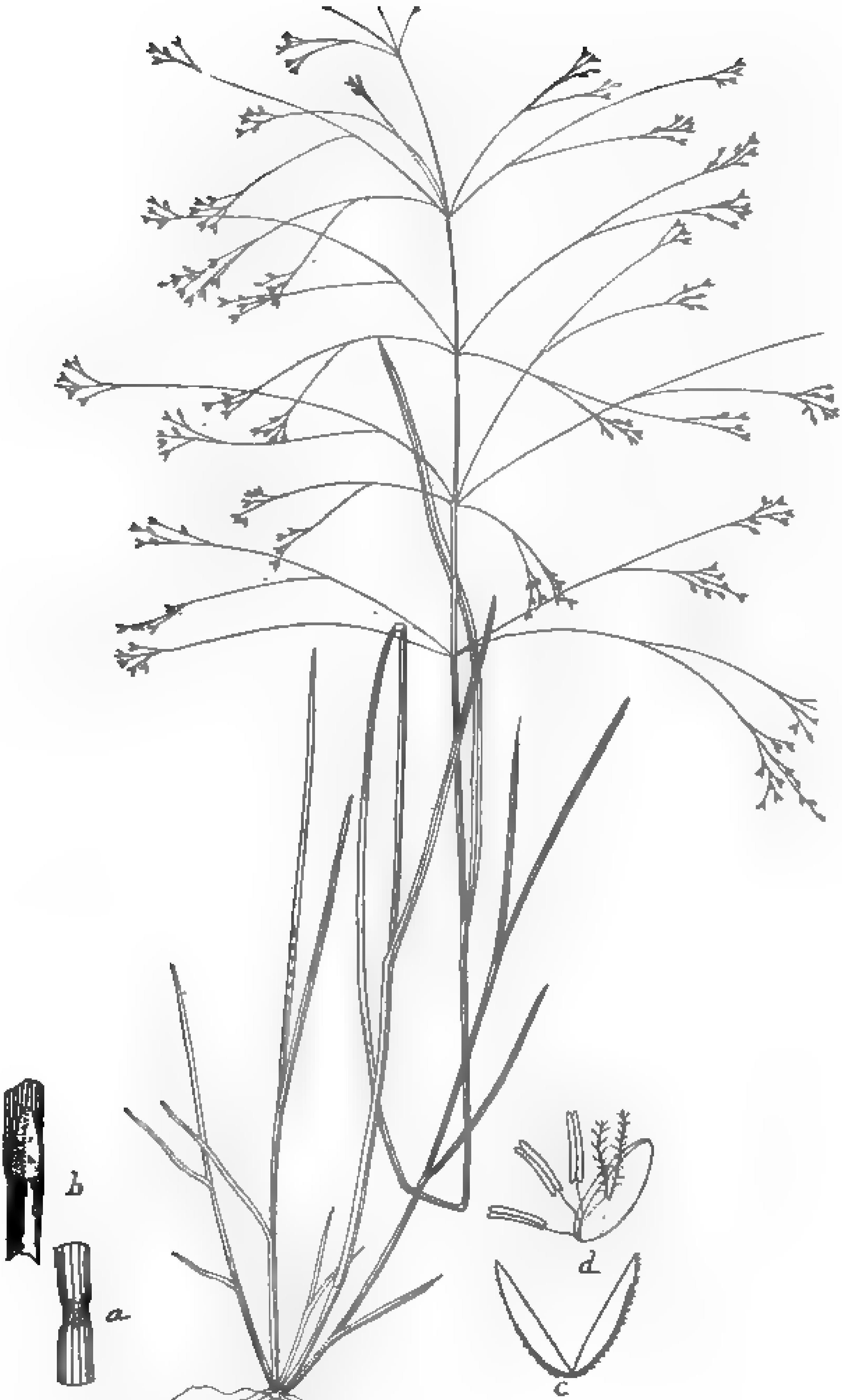


Fig. 169. Hair grass, (*Agrostis scabra*). Common in light, sandy soils where it makes some forage. a, nodes; b, sheath and blade; c, sterile glumes; d, the stamens and pistils and palea. (Charlotte M King.)

for a quarter of a century, but has not been diffused as a pasture or meadow grass. It matures early and two crops may be cut in a single season.

GRAMA GRASSES.—Three Grama grasses occur in Iowa. *Bouteloua hirsuta*, Lag., common in dry, sterile and sandy ground, scarcely worthy of attention, except on sandy, light soils as on Muscatine island.

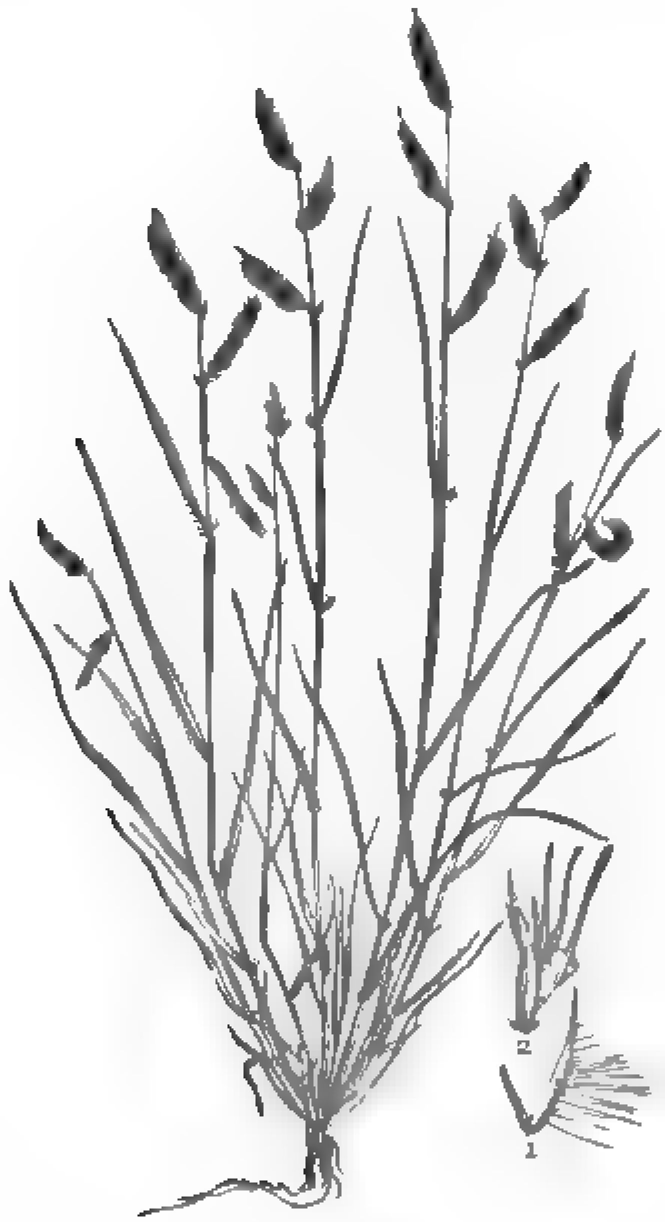


Fig. 169. Black grama, (*Bouteloua hirsuta.*) Common on Muscatine Island and in gravelly drift soils. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agri.)

The Black Grama or Tall Grama, is common only in sandy soil in the eastern portion of the state and gravelly drift soils in northern Iowa. In many respects it resembles the Blue Grama, growing in bunches; it is, however, less valuable.

The Side-oats or Tall Grama (*B. racemosa*, Lag.), is common throughout the state on dry, sterile hills, forming a large part of the natural herbage. Under cultivation it has succeeded admirably the first season, having made a growth of eighteen

inches. It is a valuable grass on the loess in western Iowa, occurring abundantly on rather dry soils. The hay made from it is of the very best quality. It cures readily, and even when cut late in the season the leaves retain their freshness longer than any other wild grasses. This is one of our best species in the state. It is found quite widely distributed on sterile hills, especially in the drift area. It is a rather stout, tufted grass, from one to three feet high, and grows in bunches. The leaves are flattened and long and the spikes are arranged along the upper portion of the stem in a one-sided fashion. This grass has been cultivated on the college grounds and has made an excellent stand in a single season, producing a fine, even turf from six inches to two feet high, and in the autumn it had developed sufficiently to produce, from a ton to a ton and a half of hay to the acre. It is certainly worthy of cultivation in dry soils. Along the loess it affords considerable pasturage.

The Blue Grama (*Bouteloua oligostachya*, Torr.) is more valuable than the former. It grows from eight to eighteen inches high, varying somewhat with the seasons. It was much taller on the average in 1896 than in 1895. As a rule, this grass seldom exceeds a foot in height. It is endowed by nature with great drouth-resisting qualities. It has been cultivated on the college grounds, and when sown in early April or late March had attained a height of eighteen inches before September 1st. Its firm leaves are highly nutritious.

Prof. Lamson-Scribner says:

"This is one of the most abundant and most valued of the Grama grasses, and extends from Wisconsin westward to California, and southward into Texas and northern Mexico. It is a perennial, six to eighteen inches high, its strong rhizomes and numerous root leaves forming dense and more or less extensive patches of excellent turf. In Montana it is known as buffalo grass. It frequents the bench lands of that state, growing at elevations from 3,000 to 4,000 or 5,000 feet, and not infrequently covers wide areas. No other grass better withstands the tramping of stock, and it is unsurpassed for grazing purposes. In the southwest it forms a large proportion of the hay delivered at the various military posts and stage stations, and is considered the best obtainable there. Like the true buffalo grass, it cures during the dry season in the turf into perfect hay, losing none of its nutritious properties."

*Bull. Div. Agros. 3:29.

Fig. 170. Side oats, (*Bouteloua racemosa.*) A grass of drift soils and of the loess of western Iowa. Valuable. a, node; b, ligules; d, flower. (Charlotte M. King.)

It is only suited for high and dry soils, and where the conditions prevail it should be grown.

CHEMICAL COMPOSITION.

Of the Grama grasses two samples were analyzed, one each of *Bouteloua oliogostachya*, and *Bouteloua racemosa*, with the following results:

NATURAL CONDITIONS.

	Water.	Fat.	Protein.	Albuminoids.	Ash.	Crude fiber.	Nitrogen free extract.
Bouteloua oligostachya—Gathered Sept. 10, 1896..	58 48	1.46	3.90	(3.20)	3.34	15.43	17.39
Bouteloua racemosa—Gathered Sept. 10, 1896...	77.88	.55	2.24	(1.79)	2.13	7.26	9.94

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Ash.	Crude fiber.	Nitrogen free extract.
Bouteloua oligostachya...........	3.48	9 40	(7.33)	8.05	37.18	41.89
Bouteloua racemosa...............	2 48	10.12	(8.11)	9.60	32.84	44.96

The following analyses, which have been selected for comparison with the above, are given to show the general chemical composition of the two grasses:

IN FRESH OR AIR-DRY MATERIAL.

	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
(1) Bouteloua oligostachya, grown in Minnesota..........	14.30	2.67	7.35	19.41	6.69	49.58
(2) Bouteloua racemosa, grown in Colorado; cut when ripe....	8.80	1.70	3.82	21.81	9.20	54.67
South Dakota (2).						
(3) Bouteloua oligostachya; collected July 10, 1891........	6.69	2.03	8.50	29.30	8.11	45.37
B. oligostachya (3)	6.10	1.70	7.40	30.30	10.50	44.10

WATER FREE SUBSTANCE.

	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
(1) B. oligostachya......	3.10	8.60	22.70	7.80	57.80
(2) B. racemosa.........................	1.90	4.20	23.90	10.10	59.90
(3) B. oligostachya........	2.18	9.11	31.40	8.69	48.62

(1) U. S. Dept. Agrl. Exp. Sta. Bull. 11: 69.
(2) Bull. S. D. Agrl. Exp. Sta. 40: 98. 1894.
(3) Bull. New Mexico Exp. Sta. 17.
Samples were analyses of the grasses as hay, not green fodder.

Fig. 171. Blue Grama, (*Bouteloua oligostachya*). One of the most valuable of the western grasses. Occurs in northern Iowa from Lyon to Dickinson county. (F. Lamson-Scribner. U. S. Dept. Agrl.)

AGROPYRON OR WHEAT GRASSES.

This genus contains quite a number of valuable grasses as well as some members that are quite difficult to exterminate, as the common quack grass (*Agropyron repens*), and as the *Agropyron occidentale* has become in eastern Minnesota. Some of the members of this genus are certainly among the most valuable of the grasses of the plains and Rocky Mountain country. Thus the *A. occidentale* is one of the most valuable grasses of the plains, while *Agropyron tenerum* and *A. pseudo-repens* and *A. richardsoni* and *A. divergens* are valuable in the foothills and mountains.

WESTERN WHEAT GRASS (*Agropyron occidentale*).—During the summer one may see along our great trunk lines a con-

spicuous bluish patch of grass on the embankments. This is the introduced Colorado blue stem or western wheat grass. It is native from Texas to Kansas, Nebraska, Iowa, Dakota and Montana. It is one of the most valuable grasses of the plains and is one of the three valuable grasses of this genus that are native to Iowa. It is common on the loess in western Iowa,

Fig. 173. Western wheat grass, (*Agropyron occidentale*). One of the most valuable grasses of the plains. Common in the dry prairies. Introduced in many portions of this state. Also native to the loess of western Iowa.

where it is used for hay and pasturage. In the northwest it is much prized as a forage plant. The yield is not large, but the quality is said to be unsurpassed. Like quack grass, it produces a large number of underground rootstocks. Lamson-Scribner says: "After two or three cuttings the yield of hay diminishes so much that it is scarcely worth the harvesting

It is then customary to drag a short-toothed harrow over the sod, which breaks up the creeping roots or underground stems, and each fragment then makes a new plant."

At various times it has been cultivated on the college farm. When sown in March a cutting of a good quality of hay may be made the same season. Though not producing so large a bulk as timothy and some other grasses, its quality is unsurpassed. A pound of western wheat grass contains more nutrient material than either blue grass or timothy. It stands drouth in a remarkable manner; the leaves and stems are bright and green during the dryest weather. The plant is much subject to the attacks of ergot, but this is not a serious objection if the hay is cut early.

This grass is a rigid, upright perennial. On the college farm during the season of 1900 it measured 2 feet and 3 inches; usually, however, it is from 1½ to 2 feet high. It produces an abundance of leaves. The leaves have a bluish color, hence the common name, Colorado blue stem. It closely resembles the common quack grass, but is much more valuable for dry places. This grass has much more solid material than quack grass. Dr. Kennedy* speaking of this grass says:

"While it does not produce as much hay to the acre as some other species, stockmen value it highly for its nutritive qualities. In Montana and the neighboring states it furnishes a considerable amount of native hay and pasturage, and is there regarded as one of the most important forage plants. This grass would make excellent hay, and should be introduced into cultivation."

F. Lamson-Scribner‡ says:

"In Montana and the neighboring states it furnishes a considerable amount of native hay, and is there regarded as one of the most important of the native forage plants. After three or four successive annual cuttings, the yield diminishes very much, but the grass is 'brought up' by letting it stand a year or two, or by dragging over the sod a sharp-toothed harrow, thus breaking the roots into small pieces, every fragment of which makes a new plant."

At the Iowa Agricultural College Experiment Station it has done exceedingly well under cultivation.

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*Bull. U. S. Dept. Agrl. Div. Agrost 62: 16.
†Bull. U. S. Dept. Agrl. Div. Agrost. 3.18.

CHEMICAL COMPOSITION.

Two samples of *Agropyron occidentale* were analyzed by the section and gave the following results:

Sample 1. June 10, 1896, wild along railroad, 30 to 32 inches high.
Sample 2. June 20, 1896, 32 to 34 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	62.64	1.76	4.56	(3.80)	10 91	3.34	16.79
Sample 2	64 63	83	3.52	(3.07)	12 07	2.74	16.11

WATER FREE SUBSTANCE.

Sample 1	4.72	12.20	(11.90)	29.21	8.93	44.94
Sample 2	2 34	9 95	(8.69)	34 14	7.75	45.82

Both samples have nearly the same amount of water present, 62.64 and 64.63 per cent, but when we compare the constituents in the dry condition we find that sample 1 has about twice the amount of fat that is present in sample 2.

Sample 1 has also more protein than No. 2, 12.20 per cent compared with 9.95 per cent; this is true with the albuminoids, 11.90 per cent for the young sample, while the older one has 8.69 per cent. There is also quite a difference in the amount of crude fiber present, 29.21 per cent for the early sample, while 34.14 per cent is present for the late sample, while the amount of nitrogen free extract is nearly the same for both of the samples, that is 44.94 and 45.82 per cent respectively. The ash, however, is somewhat larger for the younger sample.

QUACK GRASS.

In this connection a few words in regard to couch or quack grass (*A. repens*, Beauv.), which has been both condemned and praised by agricultural writers. The grass is extensively naturalized in many parts of the United States. It is frequent in many parts of this state. This species probably occurs in perhaps every county in the state, but only in small spots here and there, and it is not a factor in the production of hay in this state. Couch grass is a valuable hay grass, but, as Lamson-Scribner* says, "It binds itself out, and the sod requires

*Economic Grasses. Bull U. S. Dept. Agrl. Div. Agrost. 14:7.

breaking in order to restore the yield." This species should not be generally cultivated in this state because of its weedy character. It is a good grass for embankments, where it may be used to advantage.

CHEMICAL COMPOSITION.

The chemical composition of *Agropyron repens* may be shown by the following analyses made in the laboratory:

Sample 1. Gathered April 18, 1896, height 4 to 8 inches.
Sample 2. Gathered May 6, 1896, height 16 to 24 inches.
Sample 3. Gathered May 20, 1896, height 20 to 30 inches.
Sample 4. Gathered June 1, 1896, height 26 to 28 inches.
Sample 5. Gathered June 15, 1896, height 26 to 28 inches.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	73 96	1.15	5.13	(4 57)	6.13	3.14	10 49
Sample 2	79.06	.81	4 41	(2.47)	5.66	3 11	6.95
Sample 3	79.56	1.51	4.64	(2.11)	4 96	2.09	7.24
Sample 4	75.84	1.47	4.23	(2.04)	6.68	2.66	9.12
Sample 5	80 56	1.28	1.35	(1.32)	5.05	2.12	9.64

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	4.41	19.70	(17 57)	23.55	12.08	40.26
Sample 2	3.86	21.06	(11.80)	27.12	14.84	33.12
Sample 3	7.37	22 71	(10.34)	24.28	10 24	35.40
Sample 4	6.08	17.52	(8.44)	27 56	11.00	37.84
Sample 5	6.59	6 96	(6 80)	25.97	10.93	49.55

It will be noticed that the amount of water present is very constant, ranging from 73.96 to 80.56 per cent, and with one exception the amount of water increases as the grass becomes older. The fat present in the water free substance varies from 3.86 to 7.37 and there is no regularity regarding the amount present in the samples. We find that the greatest amount of crude protein is present in the sample collected on May 20, 1896, having a height of 20 to 30 inches. The amount of albuminoids, however, is highest in the sample of April 18th, when 4 to 8 inches high, and the amount decreases regularly as the grass grows older until it is then only 6.96 per cent in the last sample. The crude fiber is quite constant and is not regular in its changes during the growth, as shown by the analyses. The nitrogen

free extract varies from 33.12 to 49.55 per cent and the results are irregular for the successive periods of growth. The ash varies from 10.24 to 14.84 per cent and is highest in the young samples.

The above results are supplemented by the selection of other analyses of this grass from other sources.

IN FRESH OR AIR-DRY MATERIAL.

	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1, cut June 23	58.30	1.40	3.67	8.22	3.65	24.76
Sample 2, time of cutting unknown.	57 62	1.45	3 31	16.30	1.88	19.44
South Dakota (2):						
Sample 3, cut June 29, 1891; just coming in bloom	7.00	1.93	9.22	33 02	6.93	41.90

WATER FREE SUBSTANCE.

	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	3.40	8.80	19.70	8.80	59.30
Sample 2	3.40	7.80	38.50	4.50	45.90
Sample 3	2.07	9 91	35.51	7.45	45.05

FALSE COUCH GRASS.

The false couch grass (*Agropyron pseudo-repens*) is very closely allied to the common quack grass, as its name indicates. It produces tall and leafy stems, which are much softer than those of *A. occidentale*. It occurs in moist meadows in this state. It forms compact bunches, with stout stems growing from about eighteen inches to two and a half feet tall. The spikes are from four to seven inches long and somewhat stouter than in quack grass, the awns being very short. This is an excellent forage plant. It is indigenous from central Iowa northward. Thus it occurs in the vicinity of Jewell Junction, and is reported also by Mr. R. I. Cratty from the northern part of the state.

OTHER WHEAT GRASSES.

The *Agropyron tenerum*, Vasey, though not a native to many parts of this state, has been naturalized in many places, as in eastern Iowa. It is native to northwestern Iowa. This perennial grass produces an abundance of soft leaves and stems,

1. U. S. Dept. Agrl. Exp. Sta. Bull. 11:30.
2. Bull. Agrl. Exp. Sta. S D. 40: 148

Fig. 173. False couch grass, (*Agropyron pseudo-repens*). Native to the lake regions of this state. A valuable grass. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

greatly relished by stock. It has been under cultivation at Ames with remarkable success. It starts early in the spring, surpassing bluegrass, especially in its rapid growth and maturity. It is a deservedly popular grass in the Rocky Mountain region.

It is an erect perennial, grows from 3 to 4½ feet high, with numerous soft leaves and a long, slender spike. The latter height is attained especially when there is sufficient moisture and the conditions are favorable. During this season the grass only attained a height of 3½ feet, owing the dryness of the spring, but it produces a large number of leaves which are relished by stock of all kinds. It is an early and rapid grow-

Fig. 174. Slender wheat grass, (*Agropyron tenerum*). This is a valuable grass of the rocky mountain region, and has been established in numerous places in this state. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

ing grass; thus this species would permit stock to pasture several weeks earlier than any other of our common grasses. This grass also responds readily to cultivation, and the fact that it yields as well as timothy should commend it to the favorable consideration of the farmers of Iowa. Some tests of seeds furnished by the U. S. Department of Agriculture, division of Agrostology, to this station have done remarkably well, though it was also cultivated here with equal success in 1889 and 1890.

The *Agropyron caninum*, or bearded wheat grass, is native to the northwest portion of this state, but is much more common in other sections of the country. This fibrous rooted somewhat slender upright perennial grass grows from 2 to 3 feet

Fig. 175. Richardson's wheat grass, (*Agropyron Richardsoni*). Common in northwestern Iowa, and very common in the Rocky mountain region. A valuable grass. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agri.)

high. During the past season it was 3 feet high on the college grounds. It has bearded nodding heads and when grown under favorable conditions, produces a large amount of forage that is equal to some of the other species like *A. tenerum*.

Lamson-Scribner* says in regard to this plant:

"Bearded wheat grass is closely related to the more common and better known couch grass (*A. repens*), but differs markedly from that species in having no rootstocks, and in the longer beards or awns to the spikelets. No attempts have been made to introduce this grass into general cultivation, but its habit of

*Bull. U. S. Dept. Agri. Div. Agrost. Bull. 3:11.

growth and general character indicate that it may possess considerable agricultural value. It is readily propagated by seeds, which may be easily gathered."

The Richardson's wheat grass (*Agropyron richardsoni*, Schrad.) in a general way resembles quack grass. This occurs in rather dry places and grows from 2 to 3 feet high. From the fact that it does not produce the creeping rhizomes it is not so tenacious as the other species. The glumes are rather long awned, which at once separates it from the closely allied species of this region. It enters into the native composition of wild hay as far east as Kossuth county and south as far as Hamilton county in the vicinity of Mud Lake. It is abundant in the Rocky Mountain region, where it occasionally forms a considerable portion of the herbage of the "mountain parks."

CHEMICAL COMPOSITION.

Two samples of *Agropyron caninum* were analyzed and the chemical composition of the grass is shown by the following results:

Sample 1. Collected June 3, 1896, 24 to 26 inches high.
Sample 2. Collected June 15, 1896, 30 to 32 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Ash.	Crude Fiber.	Nitrogen free extract.
Sample 1	73.32	1.45	3.90	(3.83)	3.13	8.81	9.39
Sample 2	68 57	1.56	3 77	(2 92)	3 59	10 33	12.18

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Ash.	Crude Fiber.	Nitrogen free extract.
Sample 1	5 44	14.60	(14.35)	11.71	33.01	35.24
Sample 2	4 98	11.98	(9.28)	11.43	32.87	38.74

The following constituents decrease as the grass matures—water, fat, protein, albuminoids, crude fiber and ash, while the nitrogen free extract appears to increase.

The following analysis has been taken for comparison:

NATURAL CONDITION.

	Water.	Ash.	Fat.	Crude Fiber.	Protein.	Nitrogen free extract.
Cut July 18, 1892 (1)	6.09	8 00	1.80	41 23	4.67	38.21

WATER FREE SUBSTANCE.

	Water.	Ash.	Fat.	Crude Fiber.	Protein.	Nitrogen free extract.
Same as above		8.52	1.92	43.90	4.97	40 69

BLUE STEMS.

These grasses are among the most important of our native prairie grasses. In early days they constituted an important part of the forage. All of the species belong to *Andropogon*.

Fig. 176. Big blue stem, (*Andropogon provincialis*). At one time one of the most abundant of the grasses of the prairies. A good grass. (F. Lamson Scribner, Div. Agrost. U. S. Dept. of Agrl.)

1. Bull. S. D. Agrl. Exp. Sta. 40 : 152.

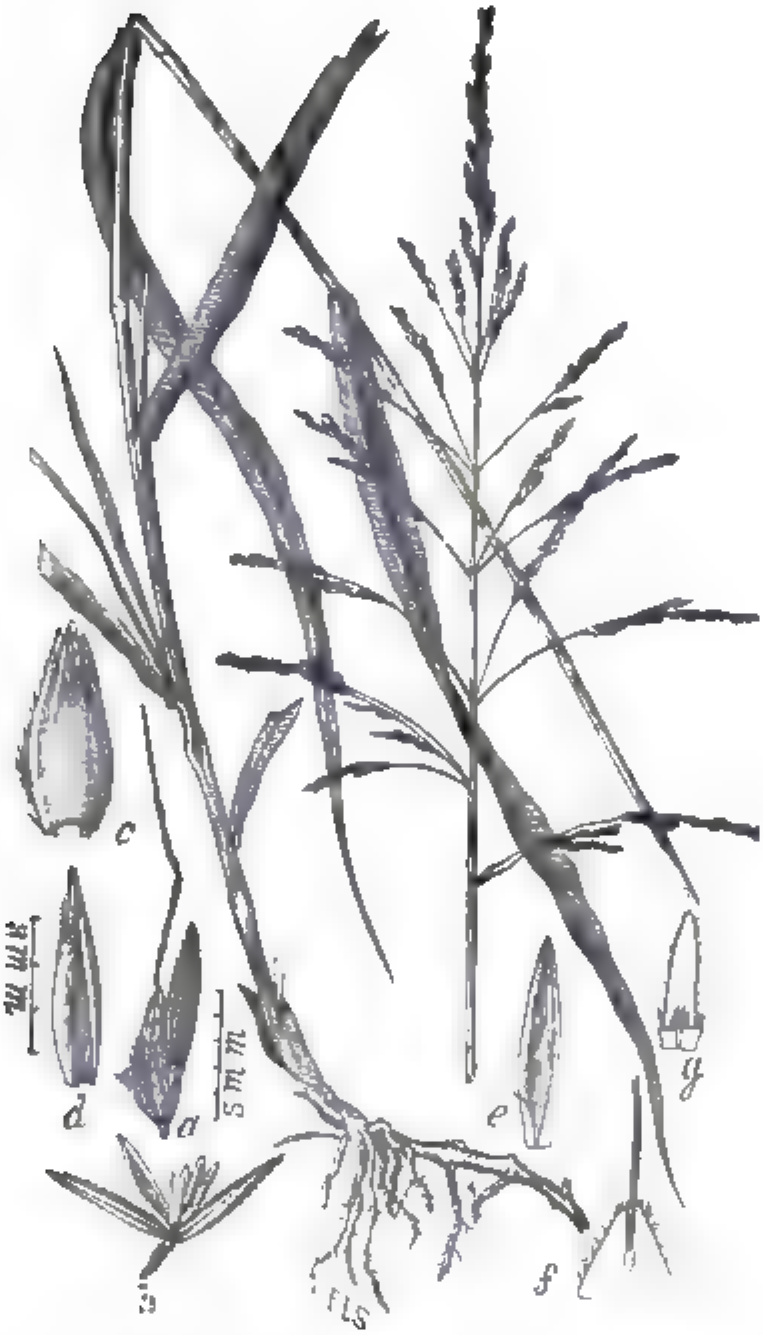

Fig. 177. Johnson grass, (*Andropogon halepensis*). Good productive grass, but very difficult to eradicate in the southern states. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. of Agrl.)

Big Blue Stem (*Andropogon provincialis*, Lam.,) is a tall growing perennial, frequently five feet high, usually four. It is a variable species, growing in bunches occasionally eight feet high and producing a large number of leaves. It is a common species throughout the state. Wherever a bit of prairie remains this grass grows in abundance. It occurs on the high, rolling prairie, rocky, open, wooded hillsides, and along alluvial creeks and river bottoms. Bluestem is an important factor in the wild hay made in the Missouri bottoms, especially in the northwestern part of Iowa. It is liked by stock, both as green forage and as hay. For horses many farmers prefer it to timothy. Bluestem hay brings a higher price in the market than any other wild hay. It starts late in the spring, and

while probably not a valuable grass for early pasturing, it is useful in late summer and autumn, provided grazing is not too close. It is an excellent grass for hay, thriving in poor, sandy, rocky soil, as well as on the richer prairie. It is less common than *Andropogon scoparius*. The allied turkey-foot grass (*A. halli hack*) is not native to the state, but is reported as naturalized near Muscatine by Barnes and Miller. It grows from three to six feet high. In western Nebraska it is considered a valuable grass.

CHEMICAL COMPOSITION.

The following five samples of *Andropogon provincialis* were analyzed in the laboratory:

Sample 1. Collected May 26, 1896, 23 to 24 inches high.
Sample 2. Collected June 5, 1896, 27 to 28 inches high.
Sample 3. Collected June 17, 1896, 36 to 37 inches high.
Sample 4. Collected June 29, 1896, 39 to 40 inches high.
Sample 5. Collected July 13, 1896, 48 to 49 inches high.

NATURAL CONDITION.

	Water.	Fat.	Albuminoids.	Crude Fiber.	Ash.	Protein.	Nitrogen free extract.
Sample 1	73.51	1.34	(1.11)	7.71	2.29	3.57	11.58
Sample 2	73.55	1.71	(2.29)	8.79	1.80	2.70	11.45
Sample 3	73.92	2.74	(1 67)	8.57	2 40	2 22	10.15
Sample 4	66.90	1.06	(1.89)	10 36	1.83	2.29	17.56
Sample 5	60 60	1 14	(4.45)	14 43	2.19	5.34	16.30

WATER FREE SUBSTANCE.

	Fat.	Albuminoids.	Crude Fiber.	Ash.	Protein.	Nitrogen free extract.
Sample 1	5 07	(4.20)	29.12	8.64	13.48	43.69
Sample 2	6.46	(8.64)	33 25	6 41	10.22	43.66
Sample 3	10.53	(6.43)	32.86	9 21	8.52	38 88
Sample 4	3.22	(5.72)	31.31	5.54	6 92	53.01
Sample 5	2 80	(11 28)	36.63	5.57	13.56	41.44

In the analyses of the samples of *Andropogon provincialis* it is readily seen that there is a tendency for the mount of water to decrease; this is not with a regular decrease in the amount, however.

In considering the constituents in the water free substance we find that the amount of fat varies between wide limits and there is no regularity in the change, sample No. 3 having the largest amount of the substance. The amount of protein and

albuminoids we find also vary, the largest amount of protein being in the last sample, cut in July, and is almost the same as the amount present in the first sample, taken in May, while the amount of albuminoids is largest in the last sample. The percentage of crude fiber increases as the plant matures, as we would expect. The amount of nitrogen free extract varies and does not change as the plant matures. The ash tends to decrease, however, as the plant matures.

Little Blue Stem (*Andropogon scoparius*, Michx.) is also common throughout the state. It grows in bunches and is a common grass on the prairies and rocky hillsides in the west, especially common in poorer soils. It is valuable for hay, yielding well, though less than big blue joint. It appears late and when not

Fig. 178. Little blue stem. (*Andropogon scoparius*) A good grass common on prairies everywhere in Iowa. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

cut or grazed too closely is useful as an autumn pasturage plant. It seeds more freely than big blue stem. Stock will eat the grass when it is young and fresh, but when old it becomes woody and somewhat unpalatable.

CHEMICAL COMPOSITION.

The five samples of *Andropogon scoparius* analyzed in the laboratory gave results as follows:

Sample 1. Collected May 27, 1896, 12 to 14 inches high. Sample heavy with water from rain.

Sample 2. Collected June 8, 1896, 14 to 16 inches high.

Sample 3. Collected June 18, 1896, 16 to 18 inches high.

Sample 4. Collected July 2, 1896, 19 to 20 inches high.

Sample 5. Collected July 22, 1896, 24 to 26 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	71.84	.82	3.34	(2.74)	8.53	2 54	12.93
Sample 2	66.12	2.05	2.60	(2.56)	10.94	3.16	15.13
Sample 3	66.98	1.23	2.65	(1.95)	11.13	2.44	15.57
Sample 4	60.76	1.39	2.94	(2.51)	12.89	2.51	19.51
Sample 5	67.26	.88	2.89	(2.12)	10 86	1.81	16.30

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	2.92	11.87	(9.75)	30.29	9.03	45.89
Sample 2	6.05	7.67	(7.57)	32.30	8.33	44 65
Sample 3	3 72	8.04	(5.93)	33.71	7.39	47.14
Sample 4	3.55	7.49	(6.40)	32 85	6.39	49.71
Sample 5	2.69	8.73	(6.41)	32.86	5.46	50.26

In considering these results the following facts present themselves: The water content of the samples vary between 60.76 per cent and 71.84 per cent. These results are not regular. The irregularity is manifested in the water free substance, as is shown in the fat present. The protein and albubuminoid percentages also are irregular, which may also be said of the crude fiber, nitrogen free extract and ash content.

The following analyses are added to the above for comparison:

NATURAL CONDITION.

	Water.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Protein.	Albuminoids.
Iowa (1): Cut Aug. 19; height, 26 inches.	56 32	2.08	.58	23.50	14 97	2 55	2.04
South Dakota (2): As hay	5.13	5 08	2'26	50 30	32 63	4 55	4 43
Connecticut (3): Cut Sept. 9.	57 08	1 72	.61	22.64	16 21	1.74	.....

WATER FREE SUBSTANCE.

Iowa (1)	....	4.77	1.32	53.81	34 27	5 83	4.68
South Dakota (2)	....	5.35	2.38	53.06	34.39	4 81	4 69
Connecticut (3)	....	4.00	1.40	52.70	37.80	4 10	.....
Mississippi (4): August 2 samples	....	4.60	.93	48 67	41.99	3.81	....

Bushy blue stem (*Andropogon nutans*, L.,) is a tall perennial, from four to six feet high, found in open woods and prairies in Iowa and eastern Nebraska, but is less common than the other members of the genus, and in this state frequently forms an important constitutent of the herbage of prairies, forming a considerable part of the prairie hay. It is cut late in the season, usually August or September, because then more easily made into hay. The hay is palatable and nutritious and cures well. Though the quantity would be less if cut by the middle of August, the quality would be superior.

Prof. F. Lamson-Scribner* says: "It is held in little esteem in the eastern and southern states, but in the west it is said to make excellent hay, and is particularly valuable because of the relatively large amount of long root leaves which it produces. All stock eat it greedily. In South Dakota it is given the first place among the native grasses as a hay-producing species, thriving best on the rich prairie bottoms. During the dry season it produces but little seed, though it usually makes a good growth of root leaves. In the middle Atlantic states this grass seeds freely and the seeds are easily collected."

1. Bull. Iowa Agrl. Exp. Sta. 11:460.
2. Bull. S. Dak. Agrl. Exp. Sta. 40:26.
3. U. S. Dept. Agr. Off. Exp. Sta. Bull. 11:39.
4. U. S. Dept. Agrl. Exp. Sta. Rec. 6:101. 1894.

*Bull. U. S. Dept. Agrl. Div. Agrost. 3:19.

Fig. 179. Bush blue stem. (*Andropogon nutans*) One of the valuable native Iowa grasses common on the edges of woods, and on prairies. (Charlotte M. King.)

CHEMICAL COMPOSITION.

The following analyses show the chemical composition of *Andropogon nutans* as analyzed in the laboratory of the experiment station:

Sample 1. Collected May 21, 1896, 23 to 24 inches high.
Sample 2. Collected June 5, 1896, 24 to 26 inches high.
Sample 3. Collected June 17, 1896, no description.
Sample 4. Collected June 29, 1896, 36 to 37 inches high.
Sample 5. Collected July 13, 1896, 40 to 42 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	77.59	.85	3.47	(.82)	6.62	2.08	9.39
Sample 2	71.28	1.74	2 57	(1.83)	9.67	2 27	12 47
Sample 3	75.77	.75	2 06	(1.65)	7.69	2.09	11.64
Sample 4	63.41	3.12	3.28	(3.03)	11.90	2.18	16.11
Sample 5	64.75	2.05	1.98	(1.50)	14.61	2.84	13 77

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1.	3 82	15 47	(3.68)	29.68	9 29	41.74
Sample 2.	6 06	8 96	(6 38)	33.66	7 91	43 41
Sample 3.	3.07	8.50	(6 82)	31.74	8.63	48.06
Sample 4.	8.55	8.92	(8.28)	32.53	5 99	44.07
Sample 5	5 83	5.61	(4.25)	41.46	8.06	39.04

The water content of the samples analyzed shows that the amount of water decreases as the plant matures. There is, however, an exception to this in the third sample. In the dry matter the fat content is irregular and the same condition exists in the relation of the amount of protein and albuminoids. In the amount of crude fiber, there is, however, a constant increase. The nitrogen free extract and ash are also irregular in the amounts present in the grass.

The following analysis is given from the S. D. Agrl. Coll. Bull. No. 40, p. 30:

AIR DRY SUBSTANCE.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample	7 75	1.57	3 85	3 62	34 73	6.40	45 70

WATER FREE SUBSTANCE.

Sample	1.70	4.17	3.87	37.64	6.94	49.54

Switch grass (*Panicum virgatum*, L.) is common and productive everywhere in central and western Iowa. It grows abundantly in native prairie sod and along railroads. It is by no means confined to the bottom land or the richer prairie soil, being frequently found on sandy or gravely drift, but it affords more and better forage on the richer soil. It is used for both hay and pasturage, but it is of much less value as a pasture grass than for hay. It has been tried in a small way under cultivation in central Iowa, with promising results. The trials have not been extensive enough, however, to recommend it for general culture. Shepard and Williams* state that it is "One of the most valuable of our native grasses. It occurs throughout the state (South Dakota) on dry and sandy as well as on rich, moist soils, though it much prefers the latter sort."

CHEMICAL COMPOSITION.

The following results were obtained from the sample analyzed in the experiment station laboratory:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Collected September 11, '97	57.47	1.08	2.71	(2.33)	14.40	4.47	19.87

WATER FREE SUBSTANCE.

Collected September 11, 1897	2.52	6 35	(5.24)	33.88	10.51	46.74

The following analyses from other stations are given for comparison:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
(1) North Carolina	8.02	1.48	7 44	33.45	5.66	43.95
(2) Tennessee, cut June 16, 1895	10 83	1 92	6 81	30.26	5.07	45.11
(3) South Dakota, July 15, 1891	7.29	2 09	6 24	33 89	6.50	43.99
(4) Mississippi	55 56	....	......	......	......	......

*Bull. South Dak. Agrl. Exp. Sta. 40:36.

WATER FREE SUBSTANCE.

(1) North Carolina	1.61	8.09	36.37	6.15	47.78
(2) Tennessee	2.15	7 64	33 93	5.69	50.59
(3) South Dakota	2.25	6.73	36.55	7.01	47.45
(4) Mississippi	1.97	3.81	39.52	4.19	50.51
Northern grown	2.40	10 50	29.80	5 60	51.70

Barnyard grass. The cultivation of *Panicum crus-galli*, L., has not been carried on extensively in this state. This grass, although usually regarded as a weed, is frequently used as a forage plant in western Iowa and along the Mississippi in eastern Iowa. It occurs abundantly as a roadside and garden weed throughout Iowa, and is a conspicuous grass in sloughs and in cornfields in the Missouri and Mississippi bottoms. Considerable success has been obtained with this grass in Massachusetts.*

F. Lamson-Scribner says:†

"At the Hatch experiment station, in Massachusetts, the crop produced was very uniform, averaging seven feet in height. The yield was at the rate of 11,207 pounds of straw per acre and 66.7 bushels of seed. When sown for silage or for soiling at the rate of one peck of seed to the acre, the yield was at the rate of from fifteen to eighteen tons per acre. A field sown July 26, after a crop of hay was removed, yielded twelve tons per acre. It is very much liked by stock, and is a valuable forage plant for feeding green or for the silo. It is not so well adapted for hay, as it is a course, succulent grass, and rather difficult to dry."

Dr. Kennedy states that from the results from seeds sent out by the division of agrostology, United States department of agriculture,‡ of the seventy-eight packages sent out for trial, most of the trials proved to be failures, owing to the lateness of planting and the severe drouth.

(1) N. C. Agrl. Exp. Sta. Bull. 90: 6.4.
(2) Tenn. Agrl. Exp. Sta. Bull. 9:112.
(3) S. D. Agrl. Exp. Sta. Bull. 40:26.
(4) U. S. Dept. Agrl. Exp. Sta. Record. 6:108.
*Ann. Rept. Mass. Agrl. Exp. Sta. 10 : 31.
†Bull U. S. Dept. Agrl. Div. Agros. 14:52.
‡Bull. U. S. Dept. Agrl. Div. Agros. 22:47.

Fig. 188. Barnyard grass, (*Panicum crus-galli.*) Common in low grounds throughout the state Especially abundant in low grounds. (Charlotte M. King.)

CHEMICAL COMPOSITION.

The sample of this grass gave the following results on analysis:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample	76.34	.73	1.43	(1.35)	9.44	2.47	9.59

WATER FREE SUBSTANCE.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample		3.09	6 07	(5.73)	39.90	10.46	40.48

The following analyses from other stations are given for comparison:

AIR-DRY CONDITION.

	Water.	Ash.	Protein.	Crude fiber.	Fat.	Nitrogen free extract.
New Mexico (1)	4.00	9.90	7 90	33.90	1.40	43.20
North Carolina (2)	7 74	8 04	4.50	33.32	1.06	46.34
South Dakota (3), Aug. 8, 1892	8.01	9.30	9.40	32.72	2.67	37.90

WATER FREE SUBSTANCE.

	Water.	Ash.	Protein.	Crude fiber.	Fat.	Nitrogen free extract.
North Carolina (2)		8.71	4.88	36 12	1.15	49.13
South Dakota (3)		10.09	10.22	35 57	2.90	41.20

Tickle grass or old witch grass (*Panicum capillare*) is an annual with coarse, branching stems, from one to three feet high, with hairy sheaths and leaves. The panicles are widely spreading. This is extremely common throughout the state, especially in old cultivated fields, frequently becoming a weedy plant. It possesses very little value as a forage plant.

CHEMICAL COMPOSITION.

But one specimen was analyzed in the station laboratory:

1. New Mexico Agrl. Exp. Sta. Bull. 17. 1895.
2. North Carolina Agrl. Exp. Sta. Bull. 90 b. 1893.
3. South Dakota Agrl. Exp. Sta. Bull. 40:38.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Collected September 10, '97.	65.09	93	3.05	(2.26)	19 82	3 10	17.01

WATER FREE SUBSTANCE.

Collected September 10, 1897......	2.65	8 75	(7.50)	31.00	8 89	48.71

The following analyses are given for comparison with the work done in our laboratory:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
(1) Mississippi*............	......	......	......	......	......	......	......
(2) South Dakota:							
Collected August 12, '92.	7.36	2.32	10.58	8.12	27.09	11.43	41 22
(3) Tennessee.........	12.17	2.14	6.88	......	34.45	6.15	38.21

*No analysis given in natural condition.

WATER FREE SUBSTANCE.

(1) Mississippi....................	2.12	13.29	......	38.21	8 12	38 26
(2) South Dakota..................	2 50	11.42	8.75	29.24	12 34	44.50
(3) Tennessee......	2 44	7.83	......	39.22	7.00	43.51

CRAB GRASS.

(*Panicum sanguinale*) is quite widely distributed throughout the state, occurs in cultivated fields and along the road-sides. In this state it grows usually from two to three feet high but frequently attains the height of four feet, in good soil. This grass makes good hay when properly cured and usually there is no trouble in curing this hay.

F. Lamson-Scribner* says: "This spontaneous growth affords excellent pasturage, as well as hay of first quality if properly cured. The stems are much b anched, and in good

(1) U. S. Dept. Exp. Sta. Record. 6:162.
(2) S. D. Bull. 40:40.
(3) Bull. Tenn. Exp. Sta. 9:112.
*Bull. U. S. Dept. Agrl. Div. Agros. 14:55.

Fig. 181. Crab grass, (*Panicum sanguinale*) to the left; common in cultivated fields. To the right, *Panicum glabrum*, common in flood plains of rivers, and becoming common in lawns (Charlotte M. King.)

soil attain a length of three to four feet. This grass contains little fiber, and dries quickly when cut, but if after cutting is wet by rains or heavy dews its value for hay is almost wholly destroyed."

CHEMICAL COMPOSITION.

One sample of this grass which was received, September 10, 1897, gave the following results on analysis:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample....	66.95	1.11	2.52	(1.98)	8 62	4 10	16.70

WATER FREE SUBSTANCE.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample......		3.34	7.61	(5.98)	26.11	12.41	50.53

The following analyses are given for comparison with the sample analyzed in our laboratory:

NATURAL CONDITION.

	Water.	Ash.	Protein.	Crude fiber.	Fat.	Nitrogen free extract.
Cut June 23 (1)....................	76 50	3.53	5 44	4.47	1.13	8.93
Mississippi (2).....................	......	......	......	......	......	......
Tennessee (3)...........	75 99	2.26	2.91	7 49	.69	10 66
No description....................	10.65	9 31	8.32	27.62	2.25	41.89
Cut August or September, 1899 ..	5.52	7.31	9.50	26 40	2 16	49 11
No description....................	6.81	8.30	5 88	28 20	2.23	48.58

WATER FREE SUBSTANCE.

	Ash.	Protein.	Crude fiber.	Fat.	Nitrogen free extract.
Cut June 23 (1)...........................	15 00	23.10	19 00	4.80	38.10
Mississippi (2).......	9.68	8.26	31.05	3.32	47 69
Tennessee (3)...	9.43	12 12	31.21	2 88	44 36
No description..........................	10.37	9.31	30 91	2.52	46 89
Cut August or September, 1889..........	7.73	10 05	27.95	2.29	51.98
No description	8.90	6 31	30.26	2.39	52 14

(1) U. S. Dept. of Agriculture, Off. Exp. Sta. Bull. 11:35.
(2) U. S Exp. Sta. Record. 6:103
(3) Bull. Agrl. Exp. Sta Tenn. 9:101, 112.

Sprouting crab grass (*Panicum proliferum*) is an annual with coarse, spreading, ascending stem, two to six feet long, with flat leaves.

F. Lamson-Scribner says:*

"It grows naturally in moist, rich soil along the banks of streams and rivers, around the shores of ponds and lakes, and in the south is often abundant in rich, cultivated fields, growing with crab grass. The stout, succulent stems are sweetish and much relished by horses and cattle. Its range is from Maine to Nebraska, and southward to the gulf, blossoming in the latter part of summer or early autumn. The spontaneous growth of this grass in cultivated fields after the removal of crops is of some value for hay or pasturage, but its cultivation cannot be recommended in view of the fact that we have many annual grasses much superior to it. In the northern and middle states it is classed with the weeds."

CHEMICAL COMPOSITION.

One sample was analyzed in the station laboratory, with the following results:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample collected Sept. 13, 1897	62 49	.95	2.36	(1 99)	11.79	8 57	13.84

WATER FREE SUBSTANCE.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample		2.57	6 30	(5.52)	31.46	22.84	36.84

The following analyses are given for comparison:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
(1) North Carolina	8 73	3 26	13.50	(2.16)	25.32	7.68	41.51
(2) Mississippi	76 86	......	......	......	......	......	......

*Bull. U. S. Dept. Agrl. Div. Agros. 14:54.

Fig. [illegible]. Sprouting crab grass, (*Panicum proliferum*). Common in fields, along roadsides and railroad embankments. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

WATER FREE SUBSTANCE.

(1) North Carolina...............	3.57	14.79	(2.36)	27 74	8 41	45.49
(2) Mississippi..................	2 52	10.98	....	31.23	9.08	46.19

Scribner's pan'c grass (*Panicum scribnerianum*) is very common in prairie meadows and affords some forage for stock. It comes on early in the season, but produces little.

CHEMICAL COMPOSITION.

The chemical composition of *Panicam scribnerianum* may be shown in the following analyses:

(1) North Carolina Exp. Sta. Bull. 90: 5:4.
(2) U. S. Dept. Agrl. Exp. Sta. Rec 6: 103.

Sample 1. Collected May 8, 1896, 5 to 9 inches high.
Sample 2. Collected May 26, 1896, 14 to 15 inches high.
Sample 3. Collected June 5, 1896, 14 to 15 inches high.
Sample 4. Collected June 17, 1896, 23 to 24 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free ext act.
Sample 1	81.20	.54	2 17	(1.58)	5.16	2.13	8 80
Sample 2	76.23	.85	2.87	(2.45)	7.85	2 19	10.01
Sample 3	71.42	.84	2 33	(1.47)	9.51	3.32	12 58
Sample 4	66.57	1.23	3 05	(2 77)	10.88	3 87	14 40

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free ext act.
Sample 1	2.87	11.51	(8.39)	27 47	11.35	46.80
Sample 2	3.60	12 09	(10 32)	33.02	9.21	42.08
Sample 3	2.96	8.16	(5.14)	33.28	11 61	43 99
Sample 4	3 67	9.14	(8.30)	32 54	11.57	43 08

The amount of water present decreases from 81.20 per cent to 66.57 per cent, and the fat present in the water free substance varies from 2.87 per cent to 3.76 per cent, the last sample having the largest percentage. The amount of protein present varies from 8.16 per cent to 12.09 per cent, the albuminoids from 5.14 per cent to 10.32 per cent, and both are irregular in the changes. The fiber changes from 27.47 per cent to 33.28 per cent, the ash from 9.21 per cent to 11 61 per cent, and these are also irregular in their changes. The largest amount of nitrogen free extract is present in the first sample, having 46.80 per cent, and the smallest amount in the second sample of 42.08 per cent. It would appear from the chemical analyses that the time most suitable for harvesting was when the last sample was taken and the grass 23 to 24 inches high.

The following analyses from other sources are added for comparison:

AIR-DRY SUBSTANCE.

	Water.	Ash.	Fat.	Crude fiber.	Protein.	Nitrogen free extract.	Albuminoids.
South Dakota (1): Collected June 20, 1891	8.83	8.88	1.71	29.64	9 97	40.97	6.63

WATER FREE SUBSTANCE.

Sample	9.74	1.83	32.51	10.94	44.91	7.25

Smooth crab grass (*Panicum glabrum*) is abundant in our river bottoms and grows from one and a half to two feet high; the stems spread over the ground, and in this way it causes a great deal of annoyance where it has been introduced. The grass may be used for forage purposes, but owing to its habit of becoming weedy in lawns, should not be used for this purpose.

CHEMICAL COMPOSITION.

One sample of this grass was analyzed and gave results as follows:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample collected September 11, 1897	71.40	1.07	1.99	(1.89)	8.61	3.45	13.48

WATER FREE SUBSTANCE.

Sample	3.73	6.96	(6.61)	30.11	12.07	47.13

Other Panic grasses.—The *P. macrocarpon* is a good woodland species, with larger leaves and stems than Scribner's panicum. The broom corn millet (*P. miliaceum*, L.) is cultivated occasionally in Iowa. It is an excellent soiling plant. Several other members of this genus are used for forage in other parts of the world. The Shama millet (*Panicum colonum*, L.) is a tropical and sub-tropical grass, and where it grows is considered one of the best forage plants. Guinea grass (*Panicum maximum*, Jacq.), native to tropical Africa, has long been cultivated in tropical America, where it yields a large amount of valuable forage, growing to a height of twelve feet. Colorado grass (*P. texanum*, Buckl.), is native to central Texas, and spoken of in the highest terms by those who have tested it.

OTHER PRAIRIE GRASSES.

WILD RYE (*Elymus robustus*, Scrib. and J. G. Sm.), is spontaneous in all parts of the state, and often forms a considerable part of the upland wild prairie hay, as well as that obtained in

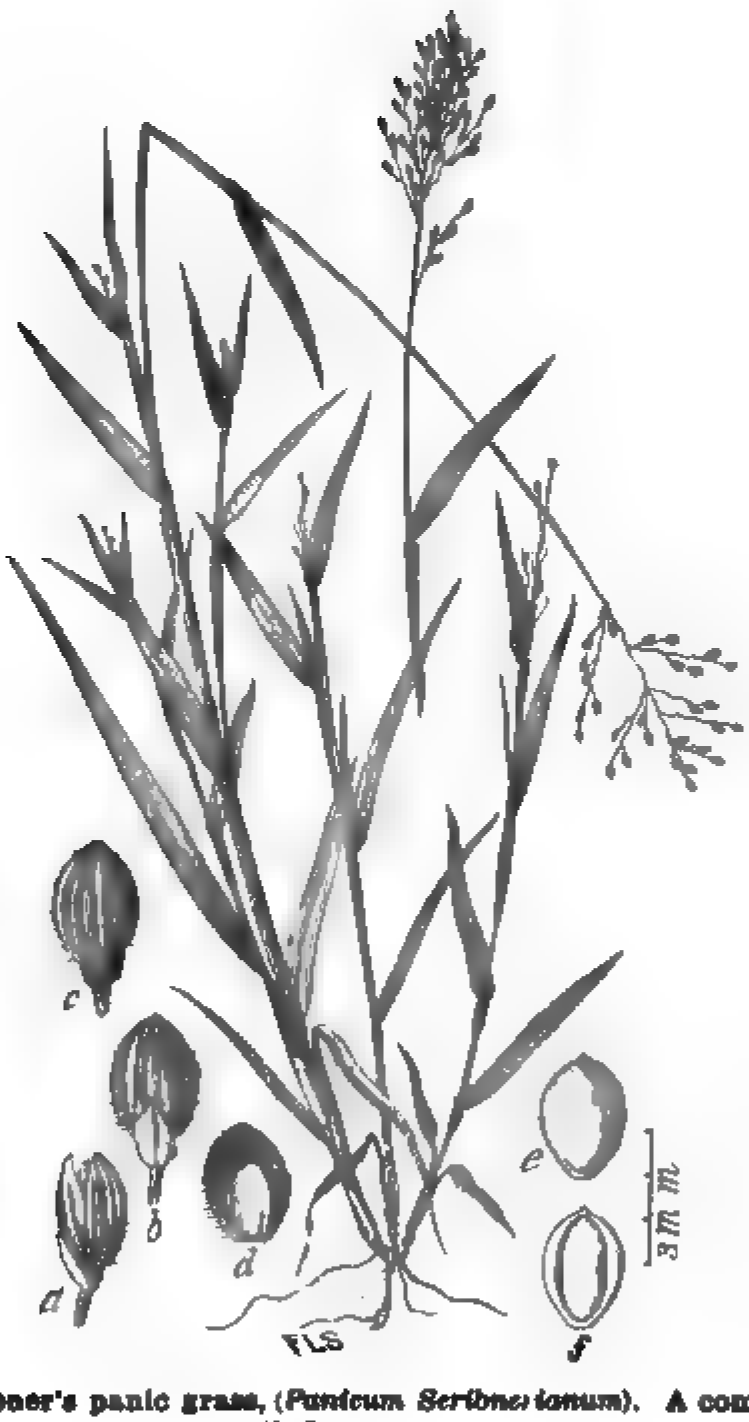

Fig. 188. Scribner's panic grass, (*Panicum Scribnerianum*). A common grass in prairies, leafing out early. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agri.)

Fig. 184. *Panicum macrocarpon.* Common at times in woods. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

Fig. 125. Broom corn millet, (*Panicum miliaceum*(. Cultivated, at times, in northwestern Iowa. Good fodder grass. (Div. Agrost. U. S. Dept. Agri.)

Fig. 186. Wild rye grass. (*Elymus robustus*). Common throughout the state. Prairies. A rapid growing species. (Charlotte M. King.)

bottoms along the Boyer and Maple rivers. It attains a height of three to five feet. The stem and leaves are harsh, and the fodder is of a very inferior quality. It is objectionable also because of the large amount of ergot found in the heads. This grass, when cut early in July, would make an admirable forage plant, but when cut, as is the usual custom in this state, in August or September, is of little value for forage purposes.

CHEMICAL COMPOSITION.

In the investigation six samples of *Elymus robustus* were analyzed, with the following results:

Sample 1. Collected April 22, 1896, height 10 to 12 inches.
Sample 2. Collected May 9, 1896, height 12 to 16 inches.
Sample 3. Collected May 29, 1896, height 28 to 30 inches.
Sample 4. Collected June 8, 1896, height 28 to 30 inches.
Sample 5. Collected June 18, 1896, height 25 to 26 inches.
Sample 6. Collected July 13, 1896, height 54 to 56 inches.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	79.32	1.40	6 04	(4 49)	4 09	2 43	6.72
Sample 2	81.44	1.14	3 88	(3 68)	5.03	2.27	6 24
Sample 3	76 68	.77	3.64	(2 56)	7 94	2 43	8 54
Sample 4	72.05	1.14	2.67	(2.35)	10.63	2.22	11.29
Sample 5	74.08	.82	2.32	(2.08)	9 54	1 76	11.48
Sample 6	45.10	.53	2 64	(2.23)	21 79	2.51	27.43

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	6.80	29.20	(21.72)	19 77	11.76	32 47
Sample 2	6.16	20 93	(19.82)	27 12	12.24	33.55
Sample 3	3.29	15 61	(10 97)	34 08	10.44	36.58
Sample 4	4.09	9 56	(8.42)	38.05	7.95	40 35
Sample 5	3.17	8.96	(8.02)	36 80	6.79	44 28
Sample 6	.97	4 72	(4 17)	39.70	4.58	50 03

In the study of the analyses made of *Elymus robustus*, the results show, as would be expected, a strong tendency for the decrease in the amount of water present in the grass in the natural condition as the grass matures. In considering the results of the water free substance it is found that the fat decreases in amount as the plant matures from 6.80 per cent to .97 per cent, with one exception. The percentage of protein decreases from 29.20 per cent to 4.72 per cent, while the albuminoids vary

from 21.72 per cent to 4.17 per cent. The percentage of crude fiber increases from 19.77 per cent to 39.70 per cent. The percentage of ash varies between 4.58 per cent and 11.76 per cent, while the nitrogen free extract increases from 32.47 per cent to 50.03 per cent. The grass represented by sample No. 3, taken on May 29, was in a very favorable condition for harvesting, when the height is a matter of consideration.

The following results have been selected for comparison with the results of this investigation:

NATURAL CONDITION.

	Water.	Ash.	Fat.	Nitrogen free extract	Crude fiber.	Protein.	Albuminoids.
Iowa (1): Cut June 25. Not headed out; 40 to 42 inches.............	66 33	3.08	.66	14.98	12 18	2.77	2.31
South Dakota (2): Cut July 2. Condition for hay.	7 54	8.61	1.64	42.77	34.16	5.28	3.68
Tennessee (3): Cut July 9. No description...	10.82	3 47	.86	48.23	32 68	3 94	.....

WATER FREE SUBSTANCE.

	Ash.	Fat.	Nitrogen free extract	Crude fiber.	Protein.	Albuminoids.
Iowa (1): Cut June 25......................	9 16	1.97	44 47	36.17	8.23	7.03
South Dakota (2): Cut July 2...........................	9.31	1.77	46.26	36 95	5.71	4 00
Tennessee (3): Cut July 9......................	3 89	.96	54.09	36.64	4.42	.....

The Canadian lyme (*E. canadensis*) is indigenous only to the loess of western Iowa, and as a forage plant is no better than the preceding. It enters in very largely to the forage of this section of the state.

TERREL GRASS (*E. virginicus*, L.) is common along streams and borders of woods. It is smooth and erect, from two to three feet high, and affords some pasturage when young. On June 15, 1900, it had grown one foot nine inches in the body of the plat, and two feet four inches on the edges. When cut in July this certainly makes a fair forage plant, but should never be cut later than July, owing to the fact that when it comes

(1) Bull. Iowa Agrl. Exp. Sta. 11 : 467.
(2) Bull. South Dakota Agrl. Exp. Sta. 40 : 158.
(3) Bull. Tennessee Agrl. Exp. Sta. 9 : 90.

Fig 187. Terrel grass (*Elymus virginicus*). Common usually in alluvial flood plains. A rapidly growing grass. (Charlotte M. King)

into flower the leaves are usually dead on the stem and the plant is harsh.

Professor Lamson-Scribner* says:

"This grass has the appearance of possessing some agricultural value. It forms an inferior turf, and by the time it blooms all the lower leaves are usually dead. When young it doubtless possesses some value as a native pasture grass. In Kansas, South Dakota and Nebraska it is regarded a valuable grass for woodland pastures."

CHEMICAL COMPOSITION.

Two samples of *Elymus virginicus* were analyzed, and the results are shown in the following:

Sample 1. Collected June 22, 37 to 38 inches high.
Sample 2. Collected June 29, 37 to 38 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	63 06	1.64	4.50	(3.76)	12.82	3.46	15.52
Sample 2	59.65	1.41	3.82	(2 56)	12 60	2.71	19 81

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	4 44	12 09	(10.19)	34.73	9.38	39 36
Sample 2	3.50	9 47	(6.35)	31.24	6.72	49.07

The difference of one week in collecting the two samples shows that there is a decrease of 3.41 per cent in the water present, and in the water free substance we find that there is a change in fat from 4.44 per cent to 3.50 per cent; in protein from 12.09 per cent to 9.47 cent, and in the albuminoids from 10.19 per cent to 6.35 per cent; in crude fiber from 31.24 per cent to 34.73 per cent, and nitrogen free extract from 39.36 per cent to 49.07 per cent; in the ash from 9.38 per cent to 6.72 per cent. As a whole, both samples being of the same height, the first sample would show that it was most suitable for cutting.

The following samples were selected for comparison with the work done here:

*Bull. U. S. Dept. Agrl. Div. Agros. 14 :35.

Fig. 189. *Elymus striatus*. Common in low ground. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
South Dakota (1): Collected July 1, 1891	8 29	3.04	6.63	5 75	27 20	7.60	47 24
Tennessee (2): Cut June 8, 1891.............	10 76	5.36	8.75	.... ..	21.77	3 71	49.65
Mississippi (3): August. 3 samples*.....	53 89	2.81	7 89	.... .	29.96	7 06	52.29

1. Bull. South Dakota Agrl Exp. Sta. 40 : 157.
2. Bull. Tennessee Agrl Exp. Sta. Vol. IX No. 3 111.
3. U. S. Dept. Agrl. Exp. Sta. Rec. 6: 101.

* Amount of water is for natural condition, and other percentages are for water free substances.

Fig. 189. Drop-seed Grass. (*Muhlenbergia sylvatica.*) Not uncommon in deep, rich woods. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. of Agriculture)

WATER FREE SUBSTANCE.

South Dakota (2)	3 31	7.23	......	29.66	8.31	51.52
Tennesse e (3)	6.01	9 81	......	24.40	4.16	55.61

OTHER RYE GRASSES.—There are many other species of rye grasses Some of these are quite valuable, especially in the western states. None of them have been tried in this state. Macoun's rye grass (*E. macounii,* Vasey) only occurs in low, moist meadows of northern Iowa. It produces a large number of leaves; it is perhaps the most valuable of any of our wild rye grasses. The *E. condensata*, the Giant rye grass of the Rocky mountain regions and Pacific slope, usually grows along rivers and streams; is useful for holding the sand on railway banks. When young it is especially valuable for hay, and furnishes a

Fig. 186a. Wild Timothy, (*Muhlenbergia glomerata.*) Common in moist meadows of northern Iowa. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

considerable amount of forage. The seeds are also used for food by the Indians. The *E. triticoides*, Nutt., is also a western species and is closely allied to the Giant rye grass. It grows from a height of two to four feet. Native to the Rocky mountains, extending eastward to Minnesota, but as yet has not been found in Iowa. It is regarded as of some value for forage purposes in the Rocky mountain region.

MUHLENBERGIA.

Several species are common throughout the state, especially Knot-root grass (*Muhlenbergia mexicana*, Trin.). This is a leafy perennial, two to three feet high, comes on early in the spring, and when used in this condition is a valuable pasture and hay

grass. When the plant comes into flower, the stem is woody and is wholly unfit for forage purposes. There are many other species of the genus, but none of them are of any value for forage purposes. All produce a vigorous growth which may be utilized when young, but when old the stems are very woody and hence is of little value for forage purposes. Wild timothy (*Muhlenbergia glomerata*, Trin.) grows in wet meadows and low grounds throughout the state, but is most common in northern Iowa. Although this grass is highly spoken of in the northwest, it is of but little value in this state.

CHEMICAL COMPOSITION.

Seven samples of *Muhlenbergia mexicana* were analyzed in the laboratory, and the results are given below:

Sample 1. Collected April 29, 1896, height 4 to 12 inches.
Sample 2. Collected May 14, 1896, height 20 to 23 inches.
Sample 3. Collected May 28, 1896, height 26 to 29 inches.
Sample 4. Collected June 8, 1896, height 36 to 38 inches.
Sample 5. Collected June 18, 1896, height 38 to 39 inches.
Sample 6. Collected June 29, 1896, height 39 to 40 inches.
Sample 7. Collected July 20, 1896, height 48 to 49 inches.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	84 82	.88	3.51	(2.73)	3 70	2.04	5.05
Sample 2	73.28	1.21	5.12	(3 78)	7.72	2 77	9.90
Sample 3	82.95	.54	2.86	(1.96)	6.43	1.95	5 27
Sample 4	77.46	.79	2 41	(2.14)	8.10	2.08	9.16
Sample 5	73 37	.81	2 13	(2.10)	9 01	2.57	12.11
Sample 6	58.77	1.49	3 22	(2.60)	13.32	2.64	20.56
Sample 7	81.98	.53	1.48	(1.09)	5 82	1.10	9.09

WATER-FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	5.81	23.16	(17 99)	24.36	13.41	83 26
Sample 2	4.52	19 17	(14.17)	28.90	10.38	37.03
Sample 3	3 14	16.77	(11.46)	37.72	11.43	30.94
Sample 4	3.49	10.70	(9.52)	35.94	9.27	40.60
Sample 5	3.03	8.00	(7.88)	33 83	9.67	45.47
Sample 6	3.62	7.81	(6 30)	32.31	6 40	49.86
Sample 7	2.95	8 26	(6.11)	32.48	6.16	50.15

In the above results we find that the amount of water present varies from 84.82 per cent to 58.77 per cent, while it might be said that the amount tends to become less as the plant

matures, yet there are exceptions, as it will be seen that the first sample collected in April, having a height of 4 to 12 inches, has only 2.84 per cent more of water than the sample taken on July 20th and having a height of 48 to 49 inches.

In considering the water free substance we find that the fat present varies from 5.81 to 2.95 per cent and that the change is not a constant one. The change in the amount of protein is constant for the first six samples and changes from 23.16 per cent to 7.81 per cent and the seventh sample having this substance to the amount of 8.26 per cent, however in the results for albuminoids we find that the decrease of this substance is constant, changing from 17.99 per cent to 6.11 per cent. The amount of crude fiber varies irregularly from 24.36 per cent in the youngest sample to 37.72 in the third sample of May 28th. The ash constituent decreases with a regular change while the nitrogen free extract increases constantly, with one exception, from 33.26 to 50.15 per cent, the exception being the third sample with 30.94 per cent. The following analyses are added for comparison:

AIR DRY SUBSTANCE.

	Water.	Ash.	Fat.	Crude fiber.	Protein.	Nitrogen free extract.	Albuminoids.
South Dakota (1): Cut Sept. 1, 1892	7.31	9.67	2.49	27.96	13.05	39.52	8.44
Tennessee (2): Not yet in bloom*	10.65	7.04	2.32	29 61	8.00	42.38	.....

WATER FREE SUBSTANCE.

	Water.	Ash.	Fat.	Crude fiber.	Protein.	Nitrogen free extract.	Albuminoids.
Sample 1	......	10.43	2.69	30.17	14.08	42.64	9.06
Sample 2	......	7.87	2 59	33.14	8.96	47.44	.....

NIMBLE WILL (*M. diffusa*, Schreb.) is common in woods and along roadsides in central and eastern Iowa. It affords some picking but in meadows is a nuisance as it is extremely hard to cut with a mower.

SLOUGH GRASS (*Spartina cynosuroides*, Willd.), coarse perennial, with erect simple stems from two to nine feet high, with long pointed leaves and numerous erect or spreading spikes,

1. S. D. Bull. Agrl. Exp. Sta. 40: 64.
2. Bull. Tenn. Agrl. Exp. Sta. 9: 90.
*Hay of grass.

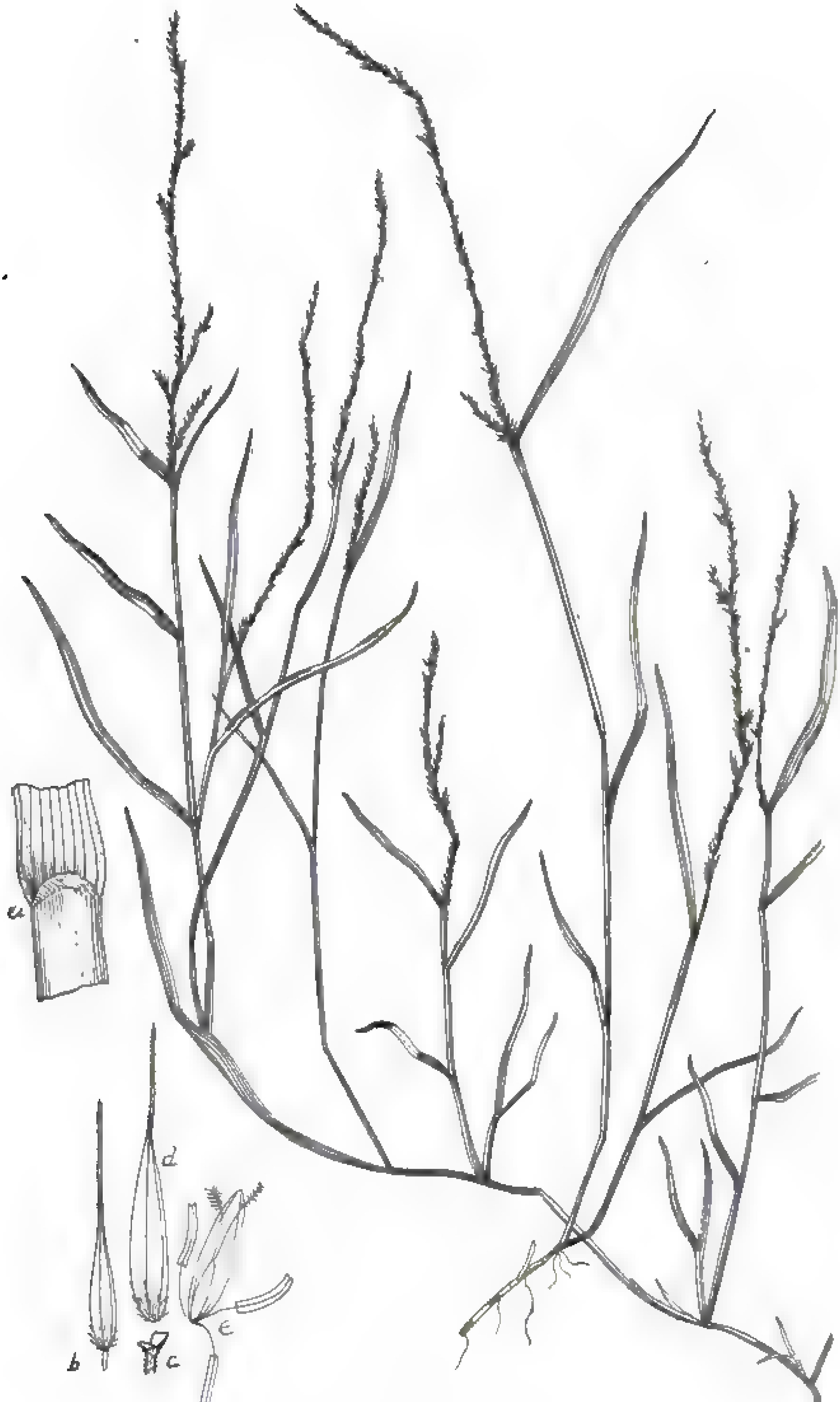

Fig. 190. Nimble Will, (*Muhlenbergia diffusa.*) A weedy lawn and woodland grass. Common in central Iowa. (Charlotte M. King.)

Fig. 181. Fresh Water Cord Grass. (*Spartina cynosuroides*) Common in the western part of the state, Missouri river bottom, and in low grounds elsewhere in the state. (Charlotte M. King.)

from two to five inches long. This is common throughout the state, especially in low places along the borders of streams, and forms an important ingredient of the forage of the Missouri river valley, where it is held in high esteem. It can only be of value when cut early. This has been grown experimentally on the college grounds and succeeded admirably, but it does not commend itself to general cultivation, owing to the more or less weedy character of the culms. It is an excellent soil binder, and for meadows where the soil is apt to be washed, it is an admirable grass. In this state it is generally known as slough grass because it occurs in low grounds. It is one of the chief grasses of the Missouri river bottoms, where it does much to keep the alluvial soil from being washed away. It is cut extensively for hay along the Missouri and Mississippi rivers, and though the fodder is course, is held in high esteem because it is productive. This hay brings less in the market than any of our other wild species.

CHEMICAL COMPOSITION.

The chemical composition of fresh water cord grass (*Spartina cynosuroides*) may be shown by the following analyses made in the laboratory:

Sample 1. Collected April 23, 1896, 6 inches to 1 foot high.
Sample 2. Collected May 7, 1896, 16 to 24 inches high.
Sample 3. Collected May 20, 1896, 36 to 38 inches high.
Sample 4. Collected June 1, 1896, 46 to 48 inches high.
Sample 5. Collected June 10, 1896, 50 to 56 inches high.
Sample 6. Collected June 20, 1896, 53 to 55 inches high.
Sample 7. Collected July 20, 1896, 62 to 63 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	71.81	1.49	4 33	(2.66)	9.19	1.89	11.29
Sample 2	69.84	.70	3.90	(3 07)	10.06	2 20	13.30
Sample 3	67.84	.70	3.74	(2.52)	11.66	2 06	14.00
Sample 4	63 32	.54	4 13	(2.90)	14 03	2.46	15.52
Sample 5	59.13	1.14	3.05	(2 10)	16 02	2.00	18.66
Sample 6	61.02	.89	2 15	(1.8)	15 44	2.07	18.43
Sample 7	56 74	1.21	3 15	(2.35)	17.19	2.87	18 84

WATER FREE SUBSTANCE.

Sample 1	5 30	15.34	(9.42)	32.61	6.71	40.02
Sample 2	2.32	12 92	(10.17)	33.38	7.29	44.09
Sample 3	2 18	11.61	(7.84)	36.27	6.40	43 54
Sample 4	1.46	11 27	(7.92)	38.24	6.70	42.33
Sample 5	2 79	7.57	(4.24)	39.21	4.90	45.53
Sample 6	2.27	5.52	(4.66)	39.62	5.32	47.17
Sample 7	2.79	7.29	(5.44)	39.73	6 62	43.57

It will be noticed that the above results show that the water content gradually decreases with one exception as the grass matures. The fat in the water free substance is largest in the youngest sample and varies in the others. The percentage of protein gradually decreases from 15.34 to 5.52 per cent in the first six samples, and then we find 7.29 per cent in the last sample. In the albuminoids we find that the amounts are not constant in their changes, the second sample having 10.17 per cent and the fifth sample 4.24 per cent. In the fiber there is a constant increase as the plant becomes matured. The nitrogen free extract increases from 40.02 per cent in the first sample, and increases to 47.17 per cent in the sixth sample. The amount of ash varies from 6.71 per cent to 4.90, and the changes are very irregular. The following analyses are added for comparison:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Iowa (1).							
Cut Aug. 27, in bloom, height, 60 inches	53 53	.63	2 57	(2.27)	16 39	2.17	24.71
Cut June 1, no heads, 60 inches	*65.36	1 63	8.41	(6.75)	38 32	6.75	44.89
Cut Aug. 27	*53 53	1.35	5.53	(4.89)	35.27	4 66	53.19
S. D., (2) July 10, 1891	† 6.45	1.21	5.29	(3 87)	38.51	4.07	50.91

NEEDLE GRASS, or porcupine grass (*Stipa spartea*, Trin.) is widely distributed in this state occurring on dry gravelly knolls. The leaves are long and wiry. It grows in bunches

* These give the water which is found in the natural condition, while the other percentages of these analyses are for the water free substances.

† The amount of water is for air dried material; the other results for the water free substance.

1. Bull. Ia. Agrl. Exp. Sta. 11: 456, 478.
2. Bull. S. D. Exp. Sta. 40: 94, 1894.

Fig. 192. Porcupine grass, or Needle grass. (*Stipa spartea*). Common prairie grass on gravelly soils. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

and develops very rapidly maturing its fruit in June. When mature the fruit with its awned flowering glumes soon fall off leaving the large pale straw colored empty glumes. The sharp pointed callus of the fruit in many cases does a positive injury to sheep. The fruit has awns which when dry are bent and much twisted. When moistened they straighten out and by the twisting and untwisting of the awn the fruit buries itself. But aside from the fact that this grass has the sharp pointed callus it is a good forage plant.

Prof. F. Lamson-Scribner* says: "It is particularly common in the prairie regions of Iowa, Nebraska, South Dakota, and Minnesota, extending westward to the Rocky mountains, where it frequently occurs upon the dry foothills and bench

*Bull. U. S. Dept. Agrl. Div. Agros. 14:71.

lands. This is the buffalo grass of the Saskatchewan region. In some localities it is known as needle grass or darning needle, but that name is reserved for *Aristida fasciculata.* It is also known as 'wild oats' in North Dakota."

CHEMICAL COMPOSITION.

Four analyses were made of *Stipa spartea* in the laboratory with the results as given below:

Sample 1. Collected May 7, 1896, 17 to 18 inches high.
Sample 2. Collected May 21, 1896, 24 to 30 inches high.
Sample 3. Collected May 26, 1896, 30 to 33 inches high.
Sample 4. Collected June 8, 1896, 48 to 49 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	71.12	1.03	4 44	(2.86)	8.41	3.35	11.65
Sample 2	67.43	1.03	2 77	(1.74)	12 35	3 01	13.41
Sample 3	67 87	.38	2.89	(2.72)	12.60	2.42	13.84
Sample 4	89 02	.25	1.02	(.82)	3.40	.91	5.40

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	3.57	15.42	(9.91)	29.12	11.61	40 28
Sample 2	3.18	8.51	(5.34)	37 92	9.24	41.15
Sample 3	1 19	9 00	(8 49)	39.22	7 52	43.07
Sample 4	2 26	9.33	(8 00)	30.96	8 21	49 24

The water percentages are found to be irregular, and in the water free substances it will be noticed that the fat is not constant in the amount present in the grass. The protein varies from 15.43 per cent to 8.51 per cent and the changes are also irregular; the albuminoids are also found to change from 9.91 to 5.34 per cent. The crude fiber increases in the first three samples from 29.12 to 39 22, and in the fourth sample we find that it changes to 30.96 per cent, and the ash percentages also change in the same order. The nitrogen free extract increases regularly from 40.28 per cent to 49.24 per cent as the grass matures. The following analysis is added for comparison:

AIR-DRY CONDITION.

	Water.	Ash.	Fat.	Crude fiber.	Protein.	Nitrogen free extract.
South Dakota. Cut June 30, 1891...	9 93	5 43	2.34	31.92	7.57	42 81

WATER FREE SUBSTANCE.

	Water.	Ash.	Fat.	Crude fiber.	Protein.	Nitrogen free extract.
Same as above		6.03	2.60	35.44	8.40	47.53

Bull. S. D. Agrl. Exp. Sta. 40:60

FEATHER BUNCH GRASS.—Allied to this grass is another bunch grass, *Stipa viridula*, Trin., or Feather Bunch Grass, which is a slender grass, from one to three feet high. It pro-

Fig. 198. Western Bunch Grass, (*Stipa viridula*). Common (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

Fig. 190. Blue Joint, (*Calamagrostis canadensis*). Common in northern and central Iowa; not infrequent in southern part of the state. (Charlotte M. King.)

duces a large number of leaves and is a much more valuable forage plant than the Needle grass. The fruiting glume is short and with a small point. This grass has been introduced along several of our railroads of the state and has also been tried under cultivation here at the Iowa Agricultural College Experiment Station. Under cultivation it succeeds admirably.

BLUE-JOINT (*Calamagrostis canadensis*, Beauv.) is common throughout central and northern Iowa and not infrequent in the southern part of the state. It is essentially a boreal species. In low marshes of northern Iowa it occupies considerable area to the exclusion of other grasses. It produces purplish panicles that resemble those of Red Top but it is easily recognized from that grass by its hairy pedicel. It grows from three to five feet high and produces a large number of leaves. Unlike some grasses the stem does not become woody after flowering. The grass yields well and produces a large amount of valuable forage which is relished by stock. Farmers in northern Iowa prize the hay very highly because it has two essential requisites, good yield, and it cures readily.

Samples of this grass were analyzed as follows;

Sample 1. Collected June 11, 1896, 25 to 26 inches high.
Sample 2 Collected June 24, 1896, 28 to 29 inches high.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	71.51	.85	2.53	(1.51)	9.81	2.60	12.70
Sample 2.	62 15	1.40	2 93	(2.71)	12 50	3.33	17.69

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	2.97	8 98	(5.30)	34 43	9.03	45.59
Sample 2	3 70	7.75	(7.17)	33 05	8.79	46.71

The following are taken for comparison with the samples analyzed in the Station's laboratory:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albumidoids.	Crude fiber.	Ash.	Nitrogen free extract.
Iowa (1). Cut July 10th*...	*58 13	1 83	4.24	(3.77)	14.30	3.49	18.01
S. D. (2). Cut June 20, '91†.	5.51	1.33	8.74	(7.13)	36.46	6.86	41.10

WATER FREE SUBSTANCE.

(1) Iowa........................	4.38	10.13	(8.58)	34.16	8.33	43.00
(2) South Dakota..................	1.41	9.25	(7.69)	38.59	7 26	43.50

It has been tried in an experimental way here at Ames and did admirably on high ground.

GRASSES OF LOW MEADOWS. Reed Canary grass (*Phalaris arundinacea* L.) is a tall, leafy perennial, produces a strong creeping root-stock and is native to low marshy ground throughout Iowa, but is most abundant in the glacial drift region of central and northern Iowa and in the low wet meadows along the Missouri. It makes a fair coarse hay. It succeeds admirably under cultivation even in dry soils. This grass when grown on the College farm was as thrifty as that growing in low bottoms. It resisted drouth as well as any grass under cultivation. Several other grasses of low marshy meadows should be mentioned. Manna grass (*Glyceria fluitans* R. Br.) which is abundant in some sections of the state. It is an excellent grass. The leaves and stems are succulent and relished by all kinds of stock. Reed meadow grass (*G. grandis Watson*) grows in low marshy places and is most abundant in northern Iowa. It is an excellent grass and forms a good portion of the grass of some meadows. It is relished by stock and makes fine hay. Wild Rice (*Zizania aquatica* L.) is abundant along the Mississippi and is an important ingredient of the vegetation of our northern lakes. Here it often forms floating islands. In such places it is nearly inaccessible for stock but along the Mississippi it grows in drier places and frequently is utilized by stock, and in drier years some is cut for hay.

1. Bull. Ia. Agrl. Exp. Sta. 11:462.
2. Bull. S. D. Agrl. Exp. Sta. 40:86.
* Not in bloom.
† In condition for hay or air-dry substance.

Fig. 196. Reed Meadow Grass, (*Glyceria grandis*). A good grass in low meadows, and liked by stock. (Div. Agrost. U. S. Dept. Agri.)

Fig. [illegible]A. Manna Grass. (*Glyceria fluitans*). An excellent grass in very low meadows; of little use, however, because meadows are usually too wet. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

BUFFALO GRASS (*Buchloe dactyloides* Engelm). The true Buffalo grass is only indigenous in Lyon county, this state, where it was found by Mr. Leiberg and Prof. Shimek. It is one of the most valuable grasses of the plains, greatly relished by stock of all kinds. It has a low spreading habit of growth, forming dense mats and rarely is more than five inches high. The fine

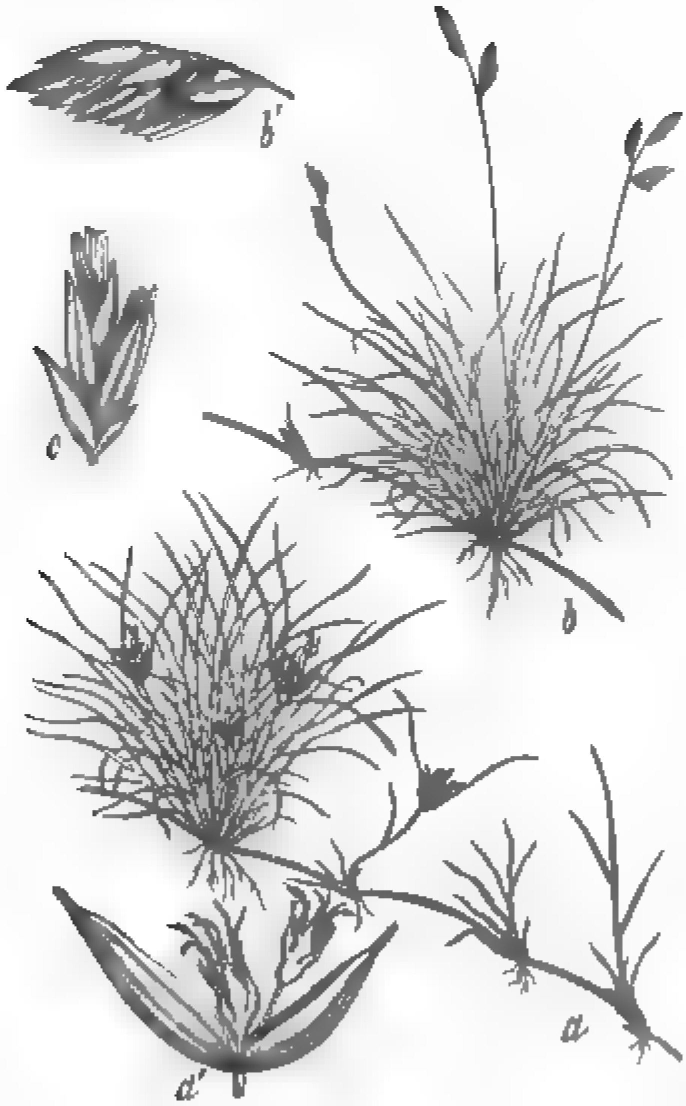

Fig. 196. Buffalo Grass. (*Buchloe dactyloides*). One of the best of the native grasses of the plains. Suited for dry hills. (Div. Agrost. U. S. Dept. Agrl.)

leaves and stems are highly nutritious. Stockmen of central and western Nebraska report it one of the best of the winter forage grasses. Like testimonials come from central and northern Texas. Lamson-Scribner* reports that it grows with great vigor in Washington, D. C, "and it may be possible to use this most palatable and nutritious grass in portions of the eastern and southern states."

SPOROBULUS —Several species of this genus are common throughout the state, and at one time were important forage plants.

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*Economic Grasses. Bull. U. S. Dept. Agrl. Div. Agrost. 14:25.

IOWA BUNCH GRASS. (*Sporobolus heterolepis*, Gray).—This is the most widely distributed of the genus in wild meadows. This grass is from two to four feet high and produces a large number of slender leaves close to the ground. It is associated with *Panicum virgatum*. Although it has scent glands like Stink grass, this is apparently not objectionable as stock is fond of it. Mr. Cratty considers it one of the best of our native bunch grasses for forage purposes.

CHEMICAL COMPOSITION.

One sample of this grass was analyzed and the results are as follows:

NATURAL CONDITION.

	Water	Fat	Protein	Albuminoids	Crude fiber.	Ash	Nitrogen free extract
Cut Sept. 13, 1897	42.06	.95	3.06	(2 46)	21.75	4.46	27.72

WATER FREE SUBSTANCE.

	Water	Fat	Protein	Albuminoids	Crude fiber.	Ash	Nitrogen free extract
		1.64	5.29	(4.37)	37.55	7.68	47.84

The following analysis is added for comparison:

AIR-DRY SUBSTANCE.

	Water	Ash	Fat	Crude fiber.	Protein	Nitrogen free extract	Albuminoids
S. D. (1). Cut Aug 17, '92..	7.90	4.82	1.65	35.11	5.65	44 87	4.93

WATER FREE SUBSTANCE.

	Water	Ash	Fat	Crude fiber.	Protein	Nitrogen free extract	Albuminoids
		5 23	1.79	38 12	6.13	48.72	5.37

DROP SEED GRASS (*S. cryptandrus*, Gray) is found throughout the state in gravelly or sandy soil and is abundant on the loess of western Iowa, where it forms a considerable part of the herbage. It is a strong rooted perennial but rather wiry. In some portions of the United States it is regarded as an important forage plant.

1. Bull. S. D. Exp. Sta. 40:7?

The *Sporobolus longifolius* is rather common in dry places and gravelly and light soils. It affords some forage although the plant is somewhat wiry. Common in drift soils along railroads.

Fig. 197. *Sporobolus longifolius*. Common in dry grounds. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

CHEMICAL COMPOSITION.

The sample of this grass analyzed gave the following results:

NATURAL CONDITION.

	Water	Fat	Protein	Albuminoids	Crude fiber	Ash	Nitrogen free extract
Sample	50.90	.72	2.86	(1 90)	18 02	4.49	23.01

WATER FREE SUBSTANCE.

	1.47	5.81	(3.98)	36.71	9.16	46.85

Sporobolus cuspidatus, like other species of the genus, is much more valuable during the earlier stages of its growth than later. It is extremely common in the loess bluffs from Sioux City southward and equally as common above Sioux City on the west slope of the river, and presumably common also from

Fig. 197A. Drop Seed Grass. (*Sporobolus cryptandrus*). A good grass, although wiry. Common in western Iowa. (F. Lamson-Scribner, Div. Agrost. U. S. Dept. Agrl.)

Sioux City north to the Minnesota line. The grass may be found occasionally as far east as Ames, Des Moines, and more or less common in Kossuth and Palo Alto counties. This grass has a well developed root system and is valuable there-

Fig. 197B. *Sporobolus cuspidatus.* Common in western Iowa. (Charlotte M King.)

Fig. 196. Stink Grass, *Eragrostis major*. A common, weedy grass. (Charlotte M. King.)

Fig. 197B. *Sporobolus cuspidatus*. Common in western Iowa. (Charlotte M King.)

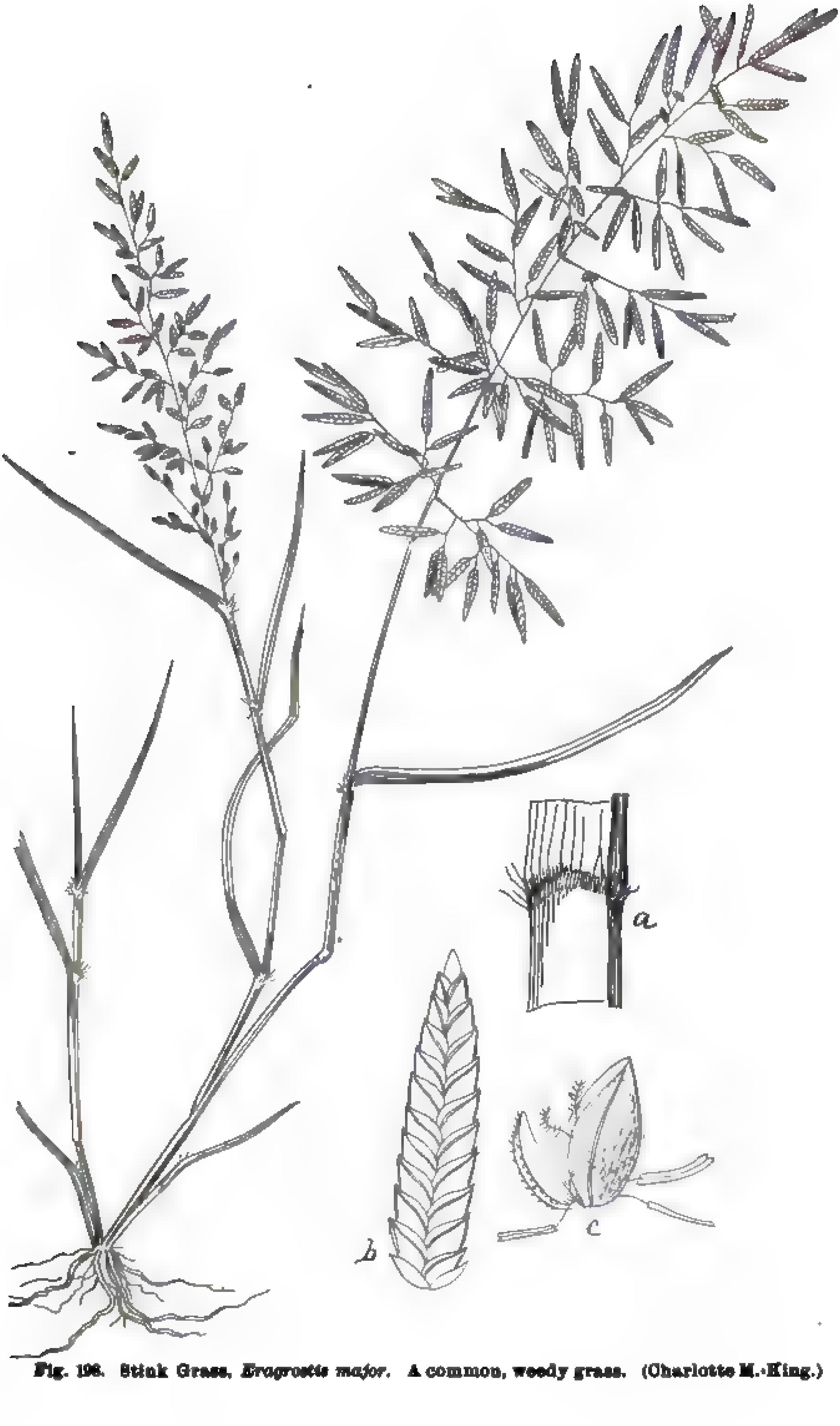


Fig. 198. Stink Grass, *Eragrostis major*. A common, weedy grass. (Charlotte M. King.)

Fig. 199. ***Eragrostis purshii.*** **A common, weedy grass. (Charlotte M. King.)**

Fig. 203. Foxtail or Pigeon Grass, (*Setaria viridis*). Common in Iowa. (Charlotte M. King.)

CHEMICAL COMPOSITION.

Only one sample of this grass was analyzed; the results are given below:

NATURAL CONDITION.

	Water	Fat	Protein	Albuminoids	Crude fiber	Ash	Nitrogen free extract
Sept. 11, 1897..	80.53	.50	2.05	(1.91)	6.86	2.92	7.14

WATER FREE SUBSTANCE.

	Water	Fat	Protein	Albuminoids	Crude fiber	Ash	Nitrogen free extract
		2.55	10.53	(9.85)	35.30	14.49	37.13

The following analyses are added for comparison:

FRESH OR AIR-DRY SUBSTANCE.

	Water	Ash	Fat	Crude fiber.	Protein	Nitrogen free extract	Albuminoids
S. D. (1.)..............	8 17	13.40	1.88	31.25	10.53	34 77	6.94
Tenn. (2):							
Nearly ripe.........	3.20	7.75	3.80	31.77	5.00	47.48	....
Washington, D. C. (3):							
Cut July 1, very y'n'g	74 20	2.80	.60	5.59	4.39	12.42	....
Cut July 24, e'rlybl'm	68 40	2 29	.84	8.14	2.86	17.47	....

WATER FREE SUBSTANCE.

	Ash	Fat	Crude fiber	Protein	Nitrogen free extract	Albuminoids
S. D (1):						
Aug. 8, 1892................	14.59	2.05	34.03	11 47	37 86	....
Tenn (2.)......................	9.04	3.93	32.82	5.16	49.05	....
Washington, D C. (3.)						
Cut July 1, very young.....	10 80	2.30	21.70	17 00	48.10	....
Cut July 24, early bloom....	7.30	2 70	25.80	9.00	55.30	....
Mississippi, (4.)...............	16.74	2.71	35.04	9 20	36.31	....

The Giant millet (*Setaria magna*, Griseb.) is, according to Lamson-Scribner,* a valuable grass for the reclamation of swampy lands along the coast. It has broad leaves and grows to the height of ten feet.

1. Bull. S. D. Agrl. Exp. Sta. 40:44.
2. Bull. Tenn. Agrl. Exp. Sta. 9:114.
3. Bull. U S. Dept. Agrl., Off. Exp. Sta. 11:38.
4. U. S. Dept. Agrl., Exp. Sta. Rec. 6:102.

*Economic Grass, Bull. Dept. Agrl. Div. Agrost. 14:28, pl. 2.

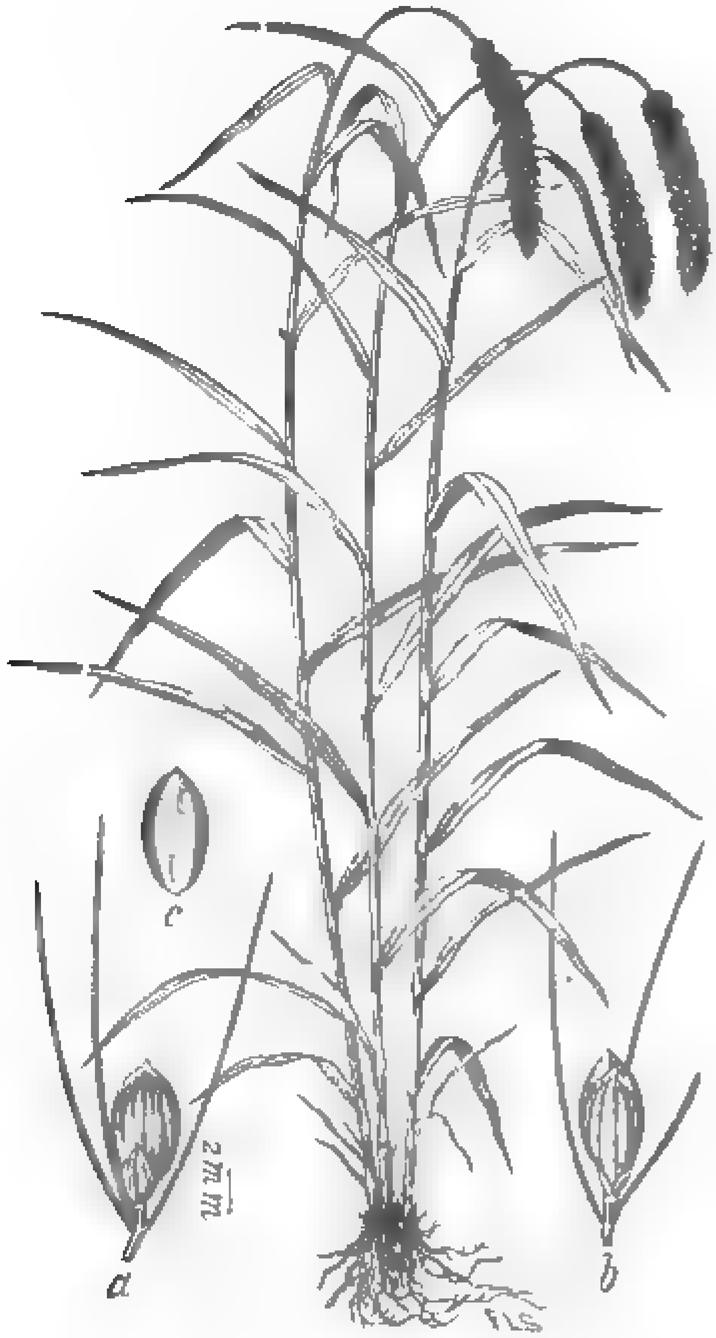


Fig. 202. German Millet. (*Setaria italica*). *a* and *b*, two views of the spikelet with three bristles; *c*, seed. (Div. Agrost. U. S. Dept. Agrl.)

MILLET, OR HUNGARIAN GRASS (*Setaria italica*) is the most important of the species occurring in Iowa. It is cultivated as a forage crop in all parts of this state, but chiefly as a catch crop. If because of unfavorable weather corn has failed to germinate, the field is sown with millet. It is usually sown about the middle of June, and in sixty or sixty-five days produces a good crop of hay, yielding from two to three tons per acre. German millet (*Setaria germanica*) is grown as frequently as Hungarian millet, but is not superior to it.

Williams* says of Hungarian grass: "This millet first came into general cultivation in the middle west. In Iowa it won favor at once, and as early as 1856 was a most valuable forage

*Yr. Bk. U. S. Dept. Agrl. 1898:274.

crop, particularly on recently broken land. Stems rather slender, clustered, branching, three to four feet high; leaves abundant, rather narrow, upright, typically bright green; heads erect or nodding slightly at maturity. Hungarian grass does not resist drouth as well as common millet, but with favorable conditions of soil and moisture it will usually give a

Fig. 203. Corean Foxtail Millet. (Div. Agrost. U. S. Dept. Agrl.)

somewhat heavier yield. One reason why Hungarian grass has not found more favor with farmers generally is that it shows a greater tendency than other common varieties to persist in the soil when allowed to mature before harvesting. In portions of the Missouri valley region, as in eastern Nebraska and Iowa, this millet received a great deal of attention from

farmers during the seventies and fine crops of hay and seed were obtained, but its tendency to 'volunteer' brought it into more or less disfavor, and it is now less commonly grown than common millet or German millet. It seldom becomes troublesome, however, except on light, sandy soils or land recently brought into cultivation. On moist, heavy soils, or in regions where there is a great deal of wet weather during the fall and winter months, it is not likely to make much volunteer growth.''

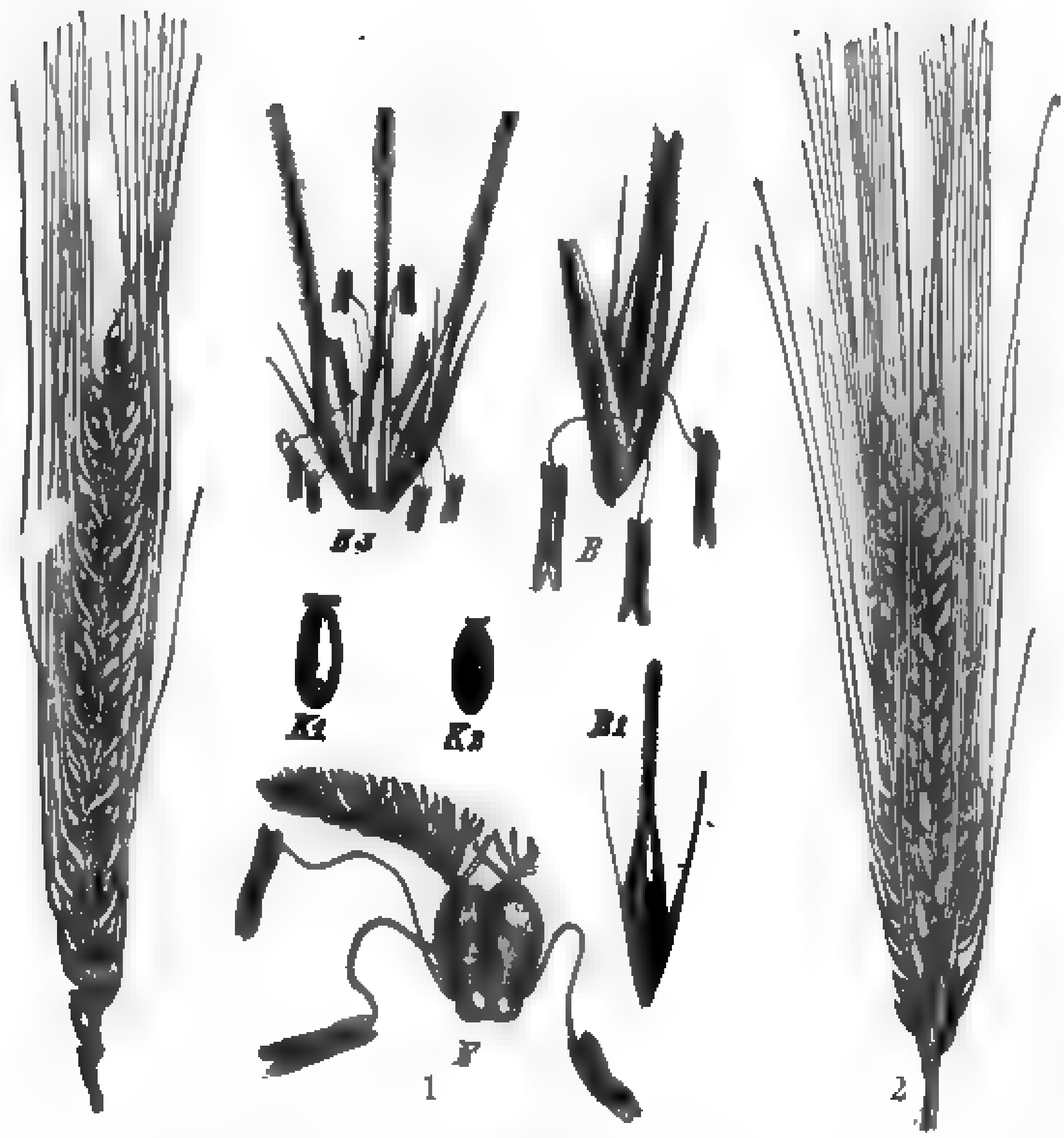


Fig. 204. Two-ranked barley, *Hordeum sativum distichon*. (After Hackel.)
1, *Hordeum sativum hexastichon*. (B 3) group of three spikelets; (B) spikelet from behind; (B1) from in front; (K1) fruit from in front; (K2) from behind. (After Nees.)
2, Common four-rowed barley, *Hordeum sativum vulgare*. (After Hackel.)

Barley.—Some of the cultivated forms of barley (*Hordeum sativum*, Jessen) are frequently cultivated in this state for forage purposes. When used for this purpose it is cut before the seed is ripe. The best time to cut is when it is in the "dough" stage.

Fig. 205. Squirrel-tail or wild barley; *b*, spikelets; *c. d.* flower. (Charlotte M. King.)

Something should also be said about squirrel-tail grass (*Hordeum jubatum*, L.) as a forage plant, since it is so common in all of our pastures and meadows. The farmer no doubt would prefer not to have the grass in his meadows, but, as he cannot help himself, the best that can be done is to allow the cattle and horses to eat the young leaves and stems. It is only of use early in the season (May) and late in the fall. If abundant in the pasture it should be cut when the heads appear.

CHEMICAL COMPOSITION.

The chemical composition of *Hordeum jubatum* may be shown in the following analyses made in this laboratory:

Sample 1. Collected May 20, 1896, height 10 to 15 inches.
Sample 2. Collected May 26, 1896, height 23 to 24 inches.
Sample 3. Collected June 5, 1896, height 23 to 24 inches.
Sample 4. Collected June 17, 1896, height 24 to 25 inches.

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	80 51	.97	4 33	(3.00)	7 13	2.19	4.87
Sample 2	72.60	1.59	3.38	(2.36)	10.10	2 35	9.98
Sample 3	67.97	.94	3.74	(2.75)	12.47	2 70	12.18
Sample 4	54.39	1.68	5.80	(3 76)	17.85	4 00	16.28

WATER FREE SUBSTANCE.

	Fat.	Protein.	Albuminoids.	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1	4.97	22.21	(15 43)	36.59	11.24	24.99
Sample 2	5.82	12.36	(8.62)	36.90	8.46	36.46
Sample 3	2 94	11.78	(8.57)	38.92	8.43	37 93
Sample 4	3.69	12.71	(8.24)	39.14	8.78	35.68

In these analyses we notice the general tendency for the amount of water to decrease as the plant matures. In the water free substance there is found to be an irregularity in the amounts of fat present in the substance, the largest amount being in the sample taken May 26, 1896. The largest quantity of protein is found in the young sample, and the same sample contains the largest amount of albuminoids, 15.43 per cent. The samples, with exception of the first, show almost the same quantities of protein and albuminoids. The quantity of fiber present increases slowly as the plant matures, and the nitrogen free extract varies and its regularity is not dependent on the maturity of the plant.

The following analyses are given for comparison:

NATURAL CONDITION.

	Water.	Fat.	Protein.	Crude fiber.	Ash.	Nitrogen free extract.
Iowa (1):						
(1) Young, 3½ to 4 inches high..	*62.29	2.06	9.39	8.70	4.94	12.62
(2) Somewhat older than No. 1..	64.35	1.48	5.37	10.20	4.52	14.08
(3) Mature grass...	56.92	1.52	3.89	14.68	4.87	18.12
South Dakota (2):						
Collected July 1, 1891..........	9.73	2.59	9.84	28.66	8.22	40.96

WATER FREE SUBSTANCE.

No. 1 Iowa...........	5.45	24.91	23.07	13.11	33.46
No. 2 Iowa..............................	4.14	15.07	28.61	12.68	39.50
No. 3 Iowa..............................	3.52	9.04	34.08	11.30	42.06
South Dakota (2)........	2.87	10.90	31.75	9.11	45.38

RYE (*Secale cereale*, L.) —Farmers do not fully appreciate the value of rye as a forage plant. It is an excellent grass and makes a good, firm hay, relished by stock of all kinds. It should be sown early in the fall, the first week in September, and in a month is ready for pasture purposes. It will stand a moderate amount of grazing when four or five inches high, and this can be kept up through the winter and early spring, and affords some good picking in April, two or three weeks in advance of bluegrass. It should be pastured cautiously. Sheep will not injure the stand as much as cattle. It has been used more extensively in the south than in the north for forage purposes.

To illustrate the chemical composition of *Secale cereale* the following analyses were made:

Sample 1. Collected April 21, 1896, 12 to 13 inches high.
Sample 2. Collected April 29, 1896, 20 to 24 inches high.
Sample 3. Collected May 4, 1896, 30 to 32 inches high, just headed.
Sample 4. Collected May 11, 1896, 30 to 36 inches high, rusted somewhat in places, just headed
Sample 5. Collected May 21, 1896, 35 to 40 inches high.
Sample 6. Collected June 3, 1896, 47 to 48 inches high.

*This sample was partly dry when received.

1. Bull. Ia. Agrl. Exp. Sta. 30:320. 1895.

2. Bull. S. D. Agrl. Exp. Sta. 40:156.

Fig. 206. Rye, (*secale cereale*). (Hackel.)

NATURAL CONDITION.

	Water.	Fat.	Protein.	Albuminoids	Crude fiber.	Ash.	Nitrogen free extract.
Sample 1....................	86.02	.84	3.94	(2.12)	2.94	1.69	4.57
Sample 2....................	85.42	.80	3.11	(2.20)	3 52	1.84	5.31
Sample 3....................	84.87	.73	2.18	(1.52)	4.25	1.68	6.29
Sample 4....................	76.81	.91	2.50	(2.39)	7.85	1.91	10.02
Sample 5....................	81.61	.82	1.76	(1.58)	6 33	2.47	7.01
Sample 6....................	76.91	.69	2.79	(1 60)	8.57	1.69	9.35

WATER FREE SUBSTANCE.

Sample 1............................	6 03	28.17	(20.95)	21.03	12.11	32.66
Sample 2............................	5.48	[illegible]	(15.10)	24.16	12.65	36.35
Sample 3............................	4.80	14.37	(10.03)	28.13	11.08	41.62
Sample 4............................	3 94	10.65	(10.31)	33.87	8.22	43.32
Sample 5............................	4 45	9.54	(8.61)	34.49	13.43	38.09
Sample 6............................	3.00	12.08	(6 92)	37.10	7.31	40.51

It will be noticed that the amount of water varies from 76.91 to 86.02 per cent. This change in the amount of water is not a constant one and is rather irregular. In the water free substance there is a decrease in the amount of fat as the plant matures, with the exception of sample five, the decrease being from 6.03 to 3.00 per cent. In the percentages of protein we find that it varies from 28.17 to 9.54 per cent, and that the decrease is a constant one with the exception of the last sample; however, in the albuminoids we find that the change is from 20.95 to 6.92 per cent, which is a constant decrease as the plant matures. In the crude fiber we have a constant increase of the amount present in the grass as it matures from 21.03 to 37.10 per cent. The ash present in the grass varies from 7.31 to 13.43 per cent and is very irregular. The nitrogen free extract is also irregular in its changes and varies from 32.66 to 43.32 per cent.

The following analyses are added for comparison with the above:

NATURAL CONDITION.

	Water.	Protein.	Nitrogen free extract.	Crude fiber.	Ash.	Fat.
Tenn. (1):						
Green fodders, sown in Sept. used for soiling in winter.....	71 52	4.61	14.25	7.08	1 28	1.26
No description	80.26	4.38	8.79	3.48	2.20	.89
No description.................	82.25	3.52	7.26	4.38	1.97	.62
No description.................	79 53	2.35	9.91	5.72	1 93	.56
Average of four	78.39	3.71	10.05	5.17	1 85	83

WATER FREE SUBSTANCE.

	Protein.	Nitrogen free extract.	Crude fiber.	Ash.	Fat.
Samples in same order as those above.					
	16 17	50 03	24.87	4.52	4 41
	22.17	44 51	17.67	11.15	4 50
	19.85	40.86	24.66	11.12	3.51
	11 49	48.39	27.93	9.44	2.75
	17.42	45.95	23.78	9.06	3.79

SORGHUM (*Andropogon sorghum* Brot.) is coming into more general use as a forage plant in this state. A great deal of it is now grown in Shelby and Jones counties for forage purposes, but its cultivation for that purpose does not compare with the area devoted to it in Kansas, as shown by Coburn.*

1. Bull. Tenn. Agrl. Exp. Sta. 9:100.

*Corn and Sorghum Rep. Kansas State Board of Agrl. 1896: 115:31.

Fig. 207. Teosinte. (*Euchlaena mexicana*). a and b, ears enclosed by husk; c and d, views of grain. A valuable forage grass. (U. S. Dept. Agr).

The amount of fodder produced is very large and it is of excellent quality. It is one of the best grasses for soiling purposes. A related grass, *Andropogon sorghum* var. *halepensis*, is the Johnson grass so well known to southern farmers. While Johnson grass is a valuable forage plant, it is decidedly objectionable where alternate husbandry is carried on, as it is almost impossible to remove it. It has been tried in this state, and on the College farm at least it does not persist. The cold winters kill it.

TEOSINT (*Euchlæna mexicana*, Schrad) is a native of Mexico and Central America and in recent years has been distributed by many seedsmen. Small fields of it may be seen here and there in the state. It is a stout leafy annual growing eight to twelve feet high and in the variety usually planted tillers, so that an enormous crop may be produced on an acre. It resembles corn in many respects. It produces a fine quality of forage and is an excellent plant for soiling purposes.

MAIZE. The value of *Zea mays*, L., (Maize or Corn) as a soiling crop has long been recognized by agriculturists. Large areas in Canada and in our northern states are cultivated solely for fodder purposes and the areas used for this purpose in Iowa are constantly increasing. A large amount of forage is annually being wasted in this state. In 1895 the acreage of corn in Iowa was 8,648,804 acres.* Probably not one-tenth of the corn fodder was saved. The value placed on corn fodder is about three dollars an acre, so that the annual corn fodder product in Iowa is worth about $30,000,000. Labor-saving machinery is revolutionizing the corn fodder question and the best farmers are now relying on corn fodder for coarse forage. It is poor economy to husk the corn and leave the stalks remain. Although cattle may obtain some forage for a few weeks, it is of poor quality, much of the digestible nutrient substances being lost when corn remains standing in the field. The drouthy year of 1894 indicated to the Iowa farmer the great value of corn stover. Before many years the larger proportion of our corn stover will be saved and the farmers of Iowa will add many million dollars to the wealth of the state. During the year 1900 it was not an uncommon sight to see more than half of the corn fodder saved for forage in central Iowa.

In another connection I have called attention to the use of Cat-tail grass (*Pennicetum typhoideum*) which is a well known

*Census of Iowa for the year 1895.

Fig. 206. Maize grown for soiling purposes.

cereal plant of Spain and Africa, but it has also been highly recommended as a forage plant It has not been grown in Ames, but in south central Iowa it has been tried with some success. Mr. Charles N. Page of the Iowa Seed company says:

"It is a wonderful forage plant of great productiveness, unexcelled, if equalled, by any other plant for its quick growth, immense size and splendid quality, and it is thought that it will prove of much value to stock farmers. It has been improved and acclimated so that it not only produces an immense crop of fodder, but will produce a good seed crop as far north as central Iowa. It is usually planted as soon as the ground

becomes warm, about corn planting time, and it begins to tiller or stool out at once. It grows to a height of twelve or fourteen feet. As many as forty-three large leafy stalks have been produced from one seed. At a distance a field of Pencillaria looks like mammoth timothy. The heads are only about an inch in diameter, but range from ten to sixteen inches in length and are closely set with thousands of small seeds. If allowed to grow until the flower heads begin to develop, before cutting, it is claimed that it will yield the heaviest crop of any fodder plant in cultivation. The best way to handle the crop is to mow it when from three to six feet in height. It will immediately start up again and can be cut several times during the season. One farmer who made a careful test says he sowed the seed on the fifteenth of May in drills eighteen inches apart. In twelve days he cultivated the crop once and it grew so rapidly after that time that it smothered out all the weeds. His first cut was made July first, forty-five days after sowing the field. The crop was about seven feet high and it weighed, green, thirty tons per acre, and when dry gave six and one half tons of hay per acre. The second growth was cut on August fourteenth, when the plants were nine feet high, and the crop weighed fifty-five tons per acre green, and eight tons dry. The third cutting was not made until October first. It weighed ten tons green, and one and one-half tons dry, thus making a total crop of ninety-five tons per acre of green fodder and when dried sixteen tons of hay."

I have not seen this grass under cultivation in this state, but it may be grown for the same purpose that teosint is and will prove valuable for soiling purposes. It has proven a valuable forage plant in other sections of the United States, especially in the south.

Pennicillaria. (Iowa Seed Co.)

Weeds of Pastures and Meadows.

In considering weeds of pastures and meadows one needs to have a clear understanding of what is meant by a weed. A weed has been defined as a plant out of place; this concise and short definition meets all the requirements.

We must first of all inquire what causes weeds to grow in pastures and meadows. In well-kept pastures and meadows weeds are seldom troublesome, but in those not well-kept the weeds are certain to appear. A pasture without a weed is not possible. It has been said that when land is well farmed weeds cannot survive. In alternate husbandry weeds ought to succumb rapidly, but in pastures and meadows it is more difficult to remove them. Weeds will only grow where there is room, where they can obtain plenty of sunshine and light. The more room, the more vigorous will the weed grow. Bailey says, "Ground may be covered with a given plant, and yet a species of wholly different character and habits may thrive along with it. If weeds, then, are to be kept out of grounds. the land must not only be occupied with some crop, but with a crop that will not allow the weed to grow with it." Now the first condition of weediness of meadow or pasture is the destruction of the turf. This is done by overstocking, or the effect of cold or drouth. The effect of overstocking is seen on the plains I have elsewhere alluded to, the conditions now prevailing in Texas. In western Nebraska, Colorado, South Dakota and Wyoming many valuable forage plants thrive, although under adverse climatic conditions. In their prime, before the range industry took hold, they supported a large number of cattle, but too close grazing and tramping has materially changed the condition of our western ranges. The valuable grasses have been killed in many cases. Toumey says: "In the early days of our great west almost the only method of travel from the Mississippi valley to our western coast and intervening points was by caravan. Wagons drawn by horses and cattle were several months in making the journey. During this time they subsisted almost entirely upon the

natural forage afforded by the country traversed. For the most part this consisted of perennial grasses which at that time were everywhere abundant. The whole of the west was then a great open pasture, unstocked save for the herds of buffalo, deer and antelope. Many regions which were then covered with a luxuriant growth of grasses are now entirely destitute of vegetation, if we exclude a few straggling, stunted bushes and the yearly crop of annuals which follow the summer rains. As a more specific case, the rancher who drove the first herd into Tonto basin, in central Arizona, found a well-pastured valley, everywhere covered with grass reaching to his horse's flanks. In passing through this region a year ago scarcely a stalk of grass was to be seen from one end of the valley to the other. This transformation has taken place in a half score of years."

Many of our most important native forage plants are perennials which naturally grow and acquire their maturity slower than annuals. The grasses which formerly covered so great an area of the west were years in developing their root systems, and in not a few species the stems were of several years' growth. In this article the author goes on to say that it will not be many years before the natural range grasses are a thing of the past. "Last year, in passing over a large unwatered area north of Prescott, miles of country were found to be covered with grass, while in much more favorable localities, in the vicinity of water, these species have entirely disappeared." The same facts are illustrated in the Mississippi valley. In many parts of Wisconsin sand prairies are common. My father often spoke of the abundance of wild forage in the early days. When he came to La Crosse, in the early fifties, the lower places were covered with a dense mass of nutritious grass. Now they yield almost nothing. The prairies of Iowa, before they were fenced and pastured, contained immense quantities of valuable nutritious grasses. Our pasturing has not only caused these grasses to diminish in quantity, but they are gradually being replaced by weeds and, in some cases, inferior grasses. Buffalo grass (*Buchloe dactyloides*) and Gamma grass (*Bouteloua*), once abundant in the west, are rapidly disappearing as an element in native forage plants of Kansas and other western states.

As a result of the overstocking of pastures, weedy annuals, like Southern Poverty-grass, Foxtail and Squirrel-tail grass

Fig. 209. Golden rod. (*Solidago canadensis*). A common weed in prairie pastures.

Fig. 209a. Golden rod, (*Solidago rigida.*) A common species in upland prairies.

spring up and take the place of the better perennial species, or the native ragweeds and verbenas spread and occupy the soil. All of these have become so plentiful that farmers remark on their more frequent occurrence now than in former years. Several rank-growing weeds are abundant in meadows and pastures of western Iowa. Sunflower and Marsh Elder find in the rich alluvial soil of the river bottoms a most congenial place for their development. They are especially troublesome on land that is often flooded during spring freshets. In addition to these the pastures throughout the state, especially in the fall or autumn, are troubled with weeds like Goldenrod. The large yellow flowered Goldenrod (*Solidago rigida*) is extremely common in native pastures after the cattle have been running all summer. Sometimes these pastures present a mass of yellow. Then again the *S. canadensis* is extremely common in similar situations Attention should be called to this goldenrod since a few years ago there was considerable discussion in veterinary papers and Garden and Forest

Fig. 216. Wild sunflower, (*Helianthus grosse-serratus*). Common in low meadows.

in regard to the poisonous effects* of these plants. Chestnut† has recently discuss-d the question and thinks that the poison resides in a fungus that grows upon the leaves of the goldenrod. In low lying meadows, especially along streams,

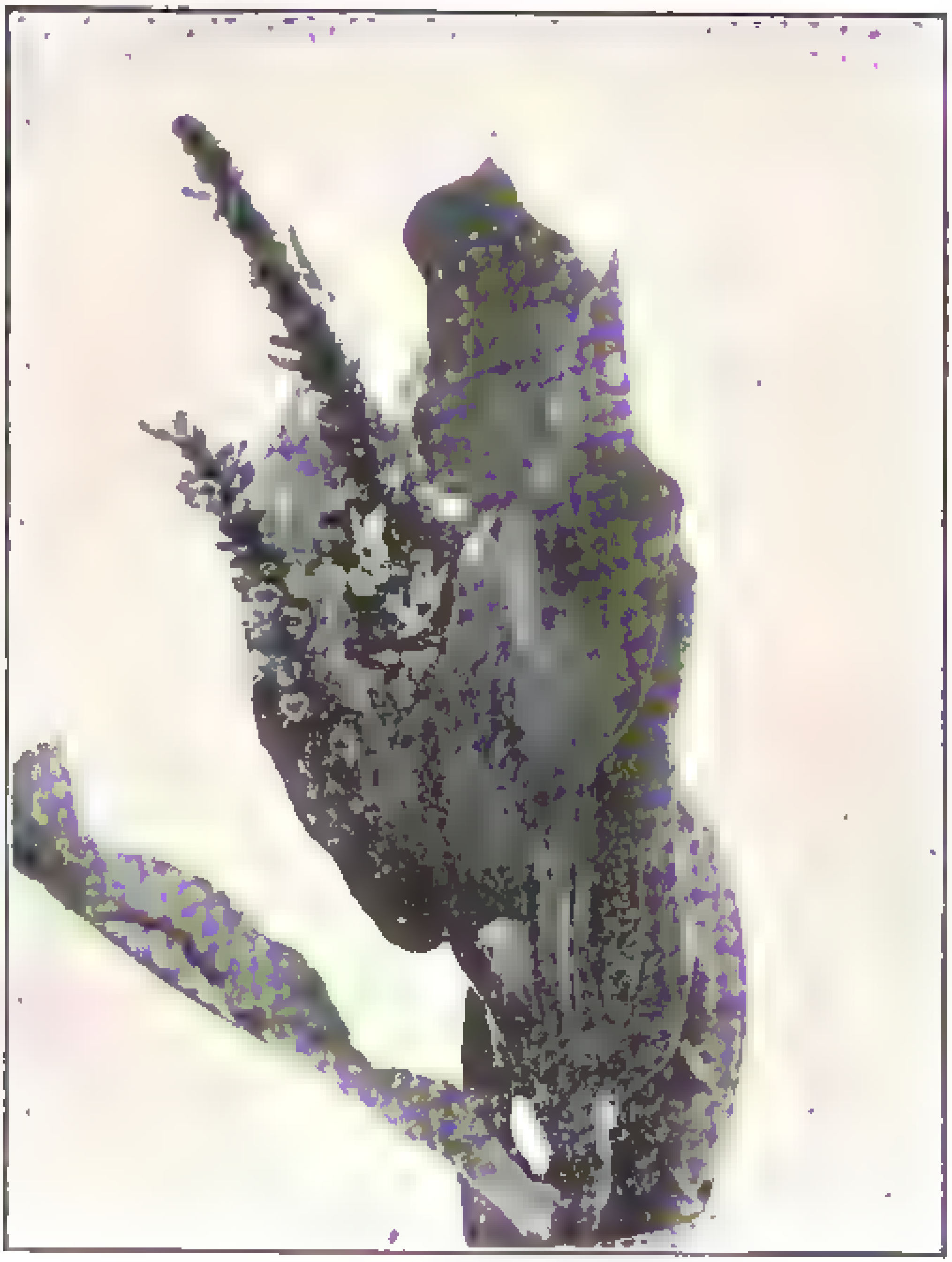


Fig. 211. Muhlenberg's smart weed, (*Polygonum muhlenbergii*). A troublesome weed in low grounds.

a large sunflower, the *Helianthus gross-seratus*, is common, some times forming large yellow masses. Where this sunflower grows in large quantities, little forage is produced. In the low-lying districts, especially swampy ground, smart weed

*J L. Scott. Goldenrod Killing Horses. Garden and Forest. 8:477.

†Preliminary Catalogue of Plants Poisonous to Stock. Rep. Bur. of Animal Industry. 15:383.

(*Polygonum muhlenbergii*) is common. This persistent perennial with scarlet flowers produces very long, thick, stout root stocks. It grows so thickly that grass is not produced. Another weed which occurs in our low wild meadows is the thistle (*Cnicus iowensis*). This biennial weed makes very little growth the first season, but the second season sends up a large, much branched stalk and produces numerous purple flowers. The allied bull thistle (*Cnicus discolor*) is especially troublesome in pastures in the timber lot. It frequently grows in such large masses as to become d cidedly noxious. Stock

Fig. 212. Common wild thistle, (*Cnicus discolor*). Common in meadows and woods.

carefully weed around this plant, thus permitting its seed to be sown broadcast in the field. Occasionally this weed may be also found in meadows.

The eastern ox-eye daisy (*Chrysanthemum leucanthemum*) is as yet a rare plant in meadows or pastures of this state. This perennial flowers during the early summer months. The large white ray flowers are very conspicuous, and though a most beautiful plant it is a most pernicious weed in the meadow.

Another plant which has recently come into notice as a troublesome weed is the rib plantain (*Plantago lanceolata*).

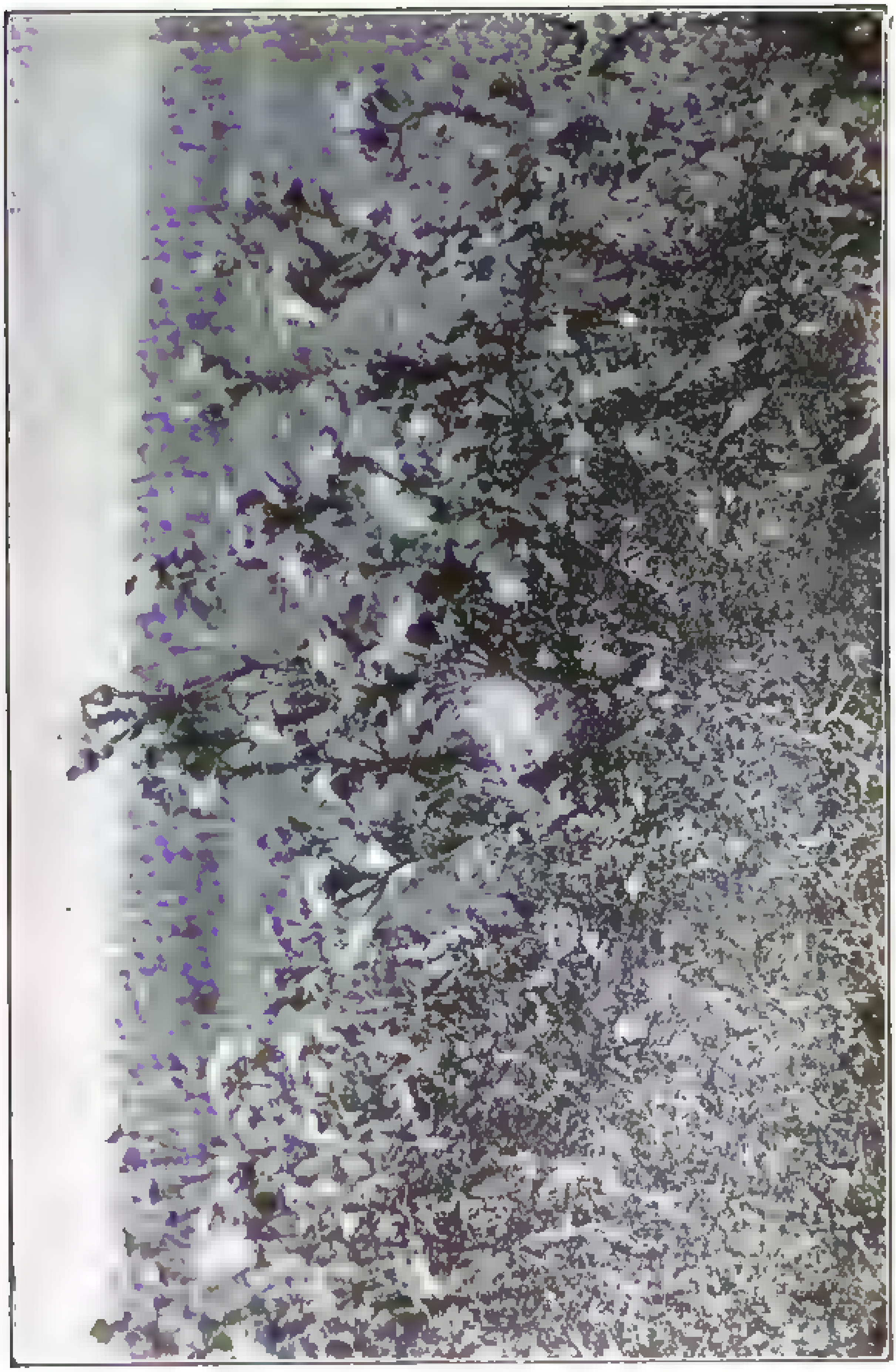


Fig. 218. Lance leaved or bull thistle, (Cnicus lanceolatus). Common in pastures and meadows. A troublesome weed.

Fig. 214. Dock (*Rumex crispus*). A most pernicious weed in many meadows of the state. (Div. Bot. U. S. Dept. Agrl)

This has been brought into the state with clover seed. It is much more common in the east than in the west and is quite easily recognized by its perennial habit and its long leaves, which are close to the ground. The flower stalk is grooved-angled from one to two feet long. It bears a cylindrical spike of flowers somewhat like the common dooryard plantain but much shorter. Like many of our other troublesome weeds, this is native to Europe.

Another European vagrant, the sheep sorrel, (*Rumex acetosella*) is widely distributed in this state. This weed spreads freely by its running root-stocks which accounts for its appearance in mats. There is a widely prevalent opinion that ground upon which it grows lacks lime. This is, however, far from correct as the weed is very common in soils which contain large quantities of calcareous matter.

An ally of the above is the curled dock (*Rumex crispus*). This pestiferous plant is widely distributed throughout the state and does much injury in meadows and pastures.*

The best method of destroying this weed is to pull it up by twisting the root and giving it a jerk. Several other species of dock are common in low meadows, especially the *Rumex altissimus*.

Sneeze weed (*Helenium autumnale*†), is a nearly smooth perennial from two to six feet high, with yellow ray flowers. It is extremely common in low grounds in many portions of the state. This weed has sometimes caused much alarm among stock men, as it is said to be very poisonous.

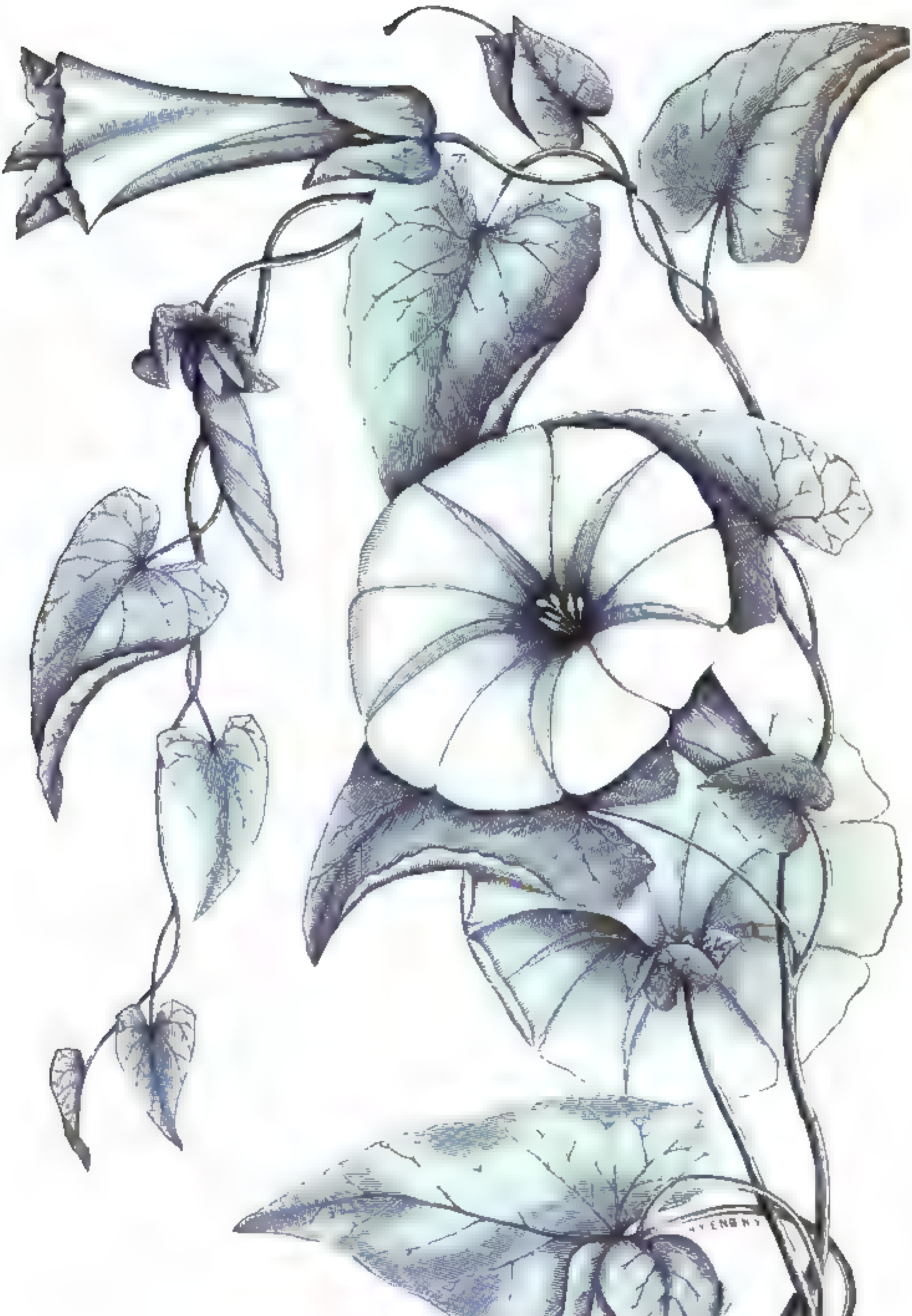
Prickly lettuce is another weedy member of the same order. It has become very common in many parts of the state. Although reported more than a quarter of a century ago by Dr. Gray, naar Cambridge, Mass., it did not become general until 1885 to 1889. Prickly lettuce (*Lactuca scariola*), is a close kin to the cultivated lettuce. It is easily recognized by its prickly or bristly stem, the prickly mid-rib of the leaf, the milky juice of the plant, and panicled inflorescence. The heads contain small, yellow flowers. This plant, when growing in open ground, is a compass plant, presenting two faces to the light. This is due to a twist in the leaf at the base where it is attached to the stem. Some years ago Dr. J. C. Arthur‡ gave a full account of this weed.

*Iowa Homestead, 1898: 1. Jl.

† Iowa Homestead, 1893: 18 Ja.

‡ Bull. Indiana Agr. Exp. Sta. 52.

Fig. 215. Milkweed. (*Asclepias cornuti*). Common in meadows. Often troublesome. Div. Bot. U S. Dept. Agri.)



sepium). Common in some meadows. (Div. Bot. U. S. Dept. Agri.)

Two weeds of the morning glory family are common in this state. One, the common European bind-weed (*Convolvulus arvensis*), is common in Missouri and Illinois, and is gradually making its way into Iowa. The writer has observed it for several years in a meadow near Ames. The common morning glory (*Convolvulus sepium*), is very closely allied to the European morning glory, and is common in low meadows where it has long been known as a persistent, troublesome weed. It differs from the European bind-weed in its much larger flowers and its longer twining stem. Not only does it shut out the light from the grass around which it grows, but it renders the hay less valuable. There is no method of exterminating this weed except in cultivated fields and then it needs the most careful attention. It must be taken up root and all or it will not subside.

Another common weed of low meadows is milk-weed (*Asclepias cornuti*). This has a deep, perennial root, opposite, oblong leaves which are soft and velvety on the lower side. The flowers are borne in large unbels, having twenty or forty in each cluster. They are light purple in color. The fruit is what is known as a follicle and two or three of these occur in one cluster, each follicle having hundreds of seeds.

Another troublesome weed; in places, is the horse nettle (*Solanum carolinense*), which spreads not only by its roots but by seed as well. It is a deep rooting perennial which propagates freely by its underground root-stocks. These root-stocks are often three feet long. The character of the plant is well shown in the accompanying cut. The corolla is light blue or white, and resembles that of the potato.*

A plant allied to the above is the buffalo burr (*Solanum rostratum*), which is an annual, growing from one to two feet high but very bushy in its habits. Buffalo burr is a prickly, hoary plant with greenish yellow somewhat divided leaves and bur-like berries. The flowers are yellow. This plant only grows in open places in the meadow, and would not occur if the meadow were kept in the right condition.†

Cowbane (*Cicuta maculata*). This plant belongs to the same family as the carrot, parsnip and celery and is a frequent inhabitant of low meadows in this state. It is easily recognized by its white flowers borne in umbels. The roots of this

* Pammel, Bull. Ia. Agr. Exp. Sta. 42:130

† Pammel, Bull. Ia. Agr Exp Sta. 28.

plant occur in bunches, e. g., fascicled They taper at the lower end. On cutting the roots a sharp, pungent odor is given off, intensified by boiling. In addition to the frequent cases of poisoning of human beings, cattle are not infrequently killed by it. Such a case was investigated by the writer some years ago, where a number of cattle died from the effects of eating the roots of the plant that grew in a meadow near a hay stack.*

Fig. 217. Cowbane, (*Cicuta maculata*). Common in low meadows Poisonous. (Div. Bot. U. S. Dept. Agrl.)

Squirrel-tail grass† has long been a troublesome weed in many parts of Iowa, Wisconsin and Illinois, and is one of our worst meadow weeds. Though originally a native of the sandy seashores from Nova Scotia to Maryland, and the upper great lakes, it has spread from the great lakes to adjoining prairie country, and now may be said to be common from the great lakes to the Rocky mountains, although there are several allied species in the Rocky mountain country. This weed is

* Pammel, Bull. Ia. Agr. Exp. Sta. 28.
†Orange Judd Farmer. 1894:28 Jl.
Bull. Ia. Agrl. Exp. Sta. 31

troublesome in both pastures and meadows. In the former it may be removed by cutting the plant before it is mature. It freqently causes injury to cattle, and even death.

Sweet clover (*Melilotus alba*) is one of the most common weeds in some pastures of the state. It is a large, tall and much branched annual with small white flowers. During the time of flowering it is extremely fragrant. It is regarded by bee keepers as a valuable honey plant, but for the north is not

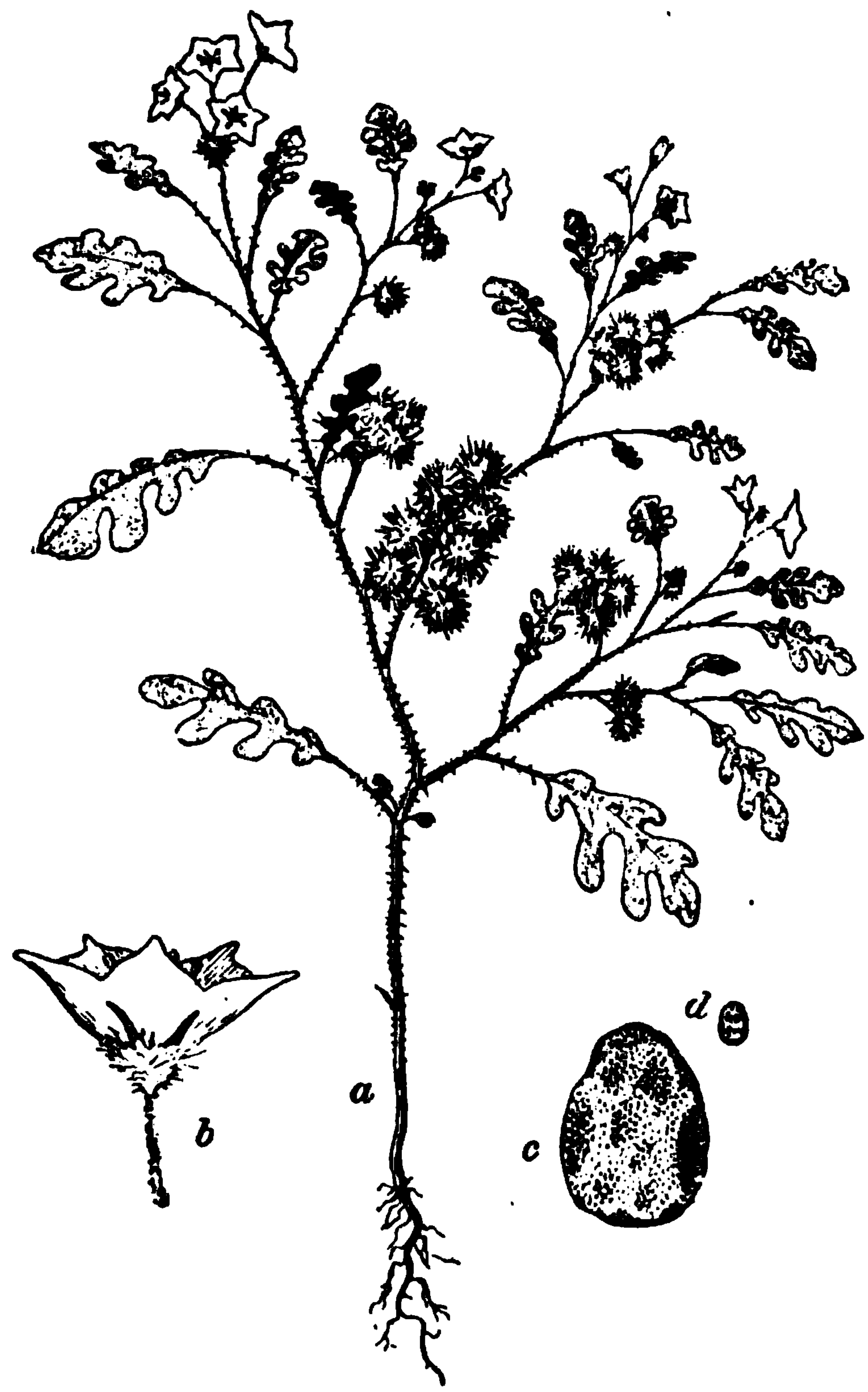


Fig. 218. Buffalo burr, (*Solanum rostratum*). Occurring in alluvial bottoms and in some meadows. (Dewey, Div. Bot. U. S. Dept. Agrl.)

considered a valuable plant for forage purposes. In the south, however, it is valuable for reclaiming waste land, as it grows not only on rich soil, but thrives on the poorest kind of land. Professor Tracy commends it as a soil renovator. Professor Goff also recommends it as a soil renovator. In this state we must regard it as a weed, in spite of the fact that the plant is useful as a soil renovator as well as a honey plant.

Fig. 319. Sweet clover, (*Melolotus alba*). Common weed in many sections of the state. (Div. Bot. U. S. Dept. Agrl.)

A few members of the mustard family are troublesome in meadows and pastures of this state. One of these, pepper grass (*Lepidium apetalum*), is abundant throughout the state, especially in timothy meadows. The flowers are small and greenish-white; the seeds are light brown, elongated, with a prominent ridge on one side. This weed is frequently found in timothy seed. The brown color of the seed attracts the

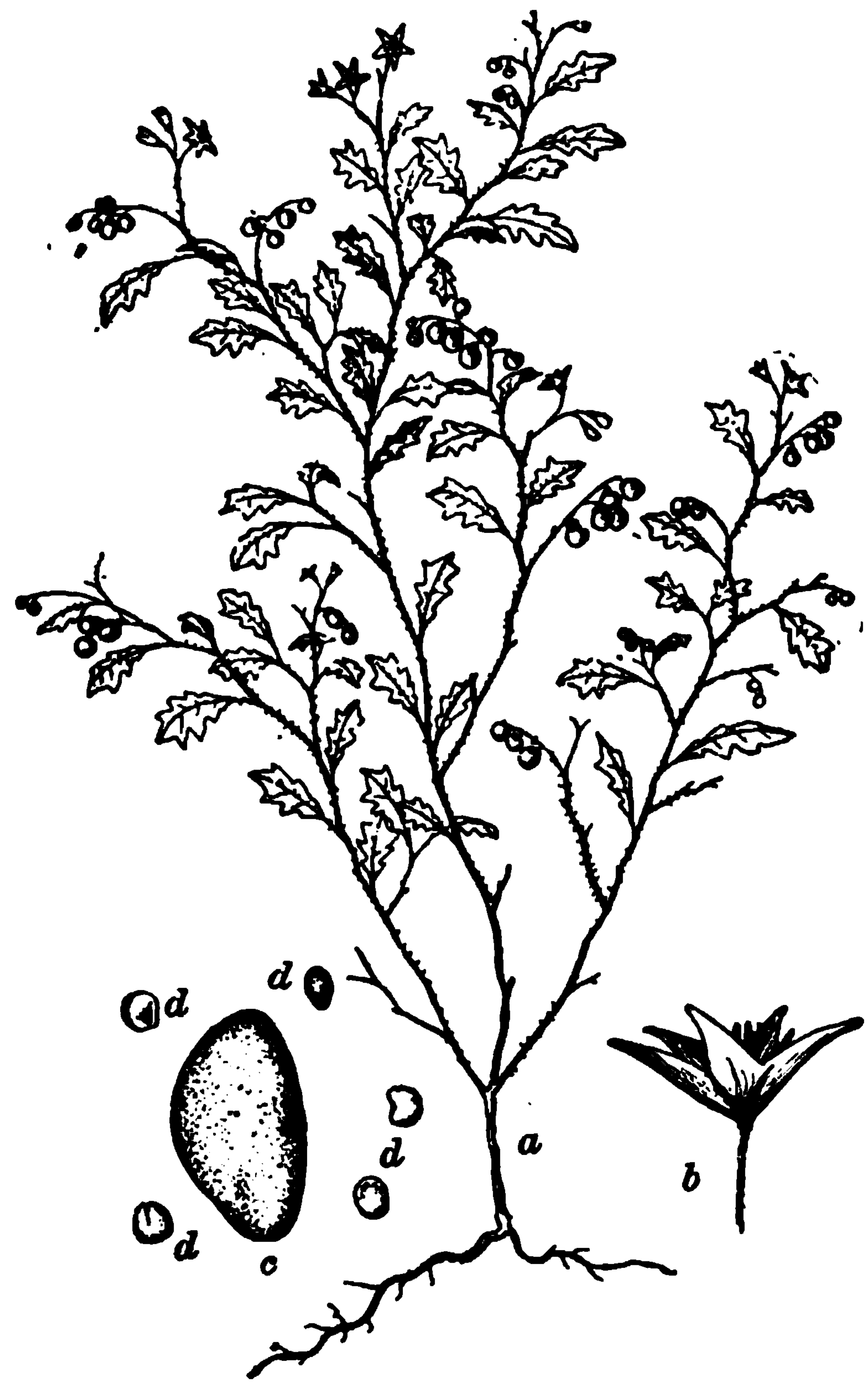


Fig. 220. Horse nettle, (*Solanum carolinense*). Troublesome weed. When once established, difficult to exterminate. (Dewey, Div. Bot. U. S. Dept. Agrl.)

attention of the seedsmen. Prof. P. H. Rolfs* identified this as one of the chief admixtures in timothy seed.

Canada thistle (*Cnicus arvensis*), though common in eastern meadows, is as yet not common in the state, although it sometimes occurs in meadows. It differs from other thistles in its small "flowers," leaves, and the perennial character of the plant.

*Bull. Ia. Agrl. Exp. Sta. 13.

CHEMISTRY OF FOODS AND FEEDING.

The value of any substance for use as a food depends largely upon two important factors; first, that of chemical composition, and second, the digestibility of the constituents which form the substance.

In connection with the study, the idea of food implies the fact that the material has in it certain constituents which the animal can use and under certain conditions they will become available to supply the demands of the various parts of the body so that a condition favorable for existence and growth is maintained.

These demands, which nature makes upon an animal in order that it may live, are largely in the form of heat to keep the body at a certain temperature, material to supply the muscular force in order that they may exert themselves when necessary and for the growth of the body.

The constituents which are found in the various foods may be classed as follows:

INORGANIC	Water. Salts, such as common salt, phosphate of lime, carbonate of potassium, and other salts.
ORGANIC	Nitrogenous, such as curd in cheese, albumin in egg, etc. Non-nitrogenous, such as starch, sugar, fats, etc.

As an illustration, if we should make an analysis of a substance such as gluten meal, the results would be stated after the following outline:

Water	9.93	Containing albuminoids 33.10.
Fat	13.46	
Protein	33.34	
Crude Fiber	33.10	
Ash	1.04	

The amount of water present in a substance varies largely according to the nature of the substance, whether green or dry. The term fat is that part of the substance which is extracted with ether. This extract is also known as crude fat from the fact that the ether extracts the waxes, coloring matters, besides the fat that is present in the food. The term

protein is used to designate that part of the substance which contains nitrogen and which may be called the nitrogenous part.

Albuminoids are those substances which form the most useful parts of the protein substances. The protein substances which are not albuminoids have the nature of substances which are called amides. These amides are of much less value for food purposes than the albuminoids.

Crude fiber is the more or less indigestible or woody parts of the food.

Ash is that part of the food which remains after burning and consists of the salts found in the food substances

The action of the digestive system may be compared to a process which is a combina ion of grinding, crushing and extracting substances in order to obtain the useful parts.

The food is first taken into the mouth where the teeth grind and crush it, breaking it into small pieces and mixing the resulting mass with the saliva. The saliva is a substance which is largely water but there is a peculiar ferment called ptyalin. This ferment when it is mixed with any substance containing starch commences to turn it to sugar. As an illustration, in order to show its composition we may take the analysis of the saliva of various domestic animals; the results being stated in parts per 1000 (*).

HORSE.

Water	992 00
Mucus and albumin	2 00
Alkaline carbonates	1.08
Alkaline chlorides	4.92
Alkaline phosphates and phosphates of lime	trace
Total	1000 00

	Cow.	Sheep.
Water	990.74	989.00
Mucus and albumin	.44	1.00
Alkaline carbonates	3.38	3.00
Alkaline chlorides	2.85	6.00
Alkaline phosphates	2.49	1 00
Phosphates of lime	.10	trace
Totals	1000.00	1000.00

In the mucus and albumin present there occurs the ferment called ptyalin. This ptyalin is always present in saliva, even

* Smith, Physiology of Domestic Animals. 271.

occurring in the saliva of very young children, and also is generally present in the saliva of other animals, with the possible exception of the dog.

The time of action of the saliva on the food varies with the nature of the animal; in man it is quite short, but in other animals such as the cow, the food is passed to the first compartment of the four-chambered stomach, and when a supply of food has been gathered it is returned to the mouth to be thoroughly ground and crushed by the teeth and well mixed with the saliva. It then passes to the other parts of the stomach for further digestion. In the horse the crushed and ground mass which has been thoroughly mixed with saliva passes to the stomach, where the ptyalin acts for a while and the juices of the stomach are apparently withheld in order that the change of the starch to sugar may continue for a time.

The ptyalin acts at a temperature slightly above 104° F. Small quantities of free acids will prevent the ptyalin acting on starch. Some salts like magnesium sulphate in very small quantities accelerate, while larger quantities hinder, the action of the enzyme.

The glands in the mouth which secrete the saliva are the most active in the animal body, secreting as they do eight to fourteen times their entire mass in saliva. The food, after having been ground and mixed with the saliva, passes to the stomach*. Here it meets with a condition which is entirely different from that in the mouth. In the stomach we find a liquid called the gastric juice. It is similar to the saliva in containing a large quantity of water, as may be seen in the following analysis† (parts per 1000):

	Human.	Dog.	Sheep.
Water	994.404	973.062	986.143
Organic substance	3.195	17.127	1.234
Hydrochloric acid	.200	3.050	1.234
Calcium chloride	.061	.624	.114
Sodium chloride	1.465	2.507	4.369
Potassium chloride	.550	1.125	1.518
Ammonium chloride	....	.486	.473
Calcium phosphate, Magnesium phosphate, Ferric phosphate	.125	.226	.577

* The saliva also acts in a mechanical manner, aiding the passage of the food to the stomach, or in other words, as a lubricant.

† Halleburton, Chem., Phys. and Path. p. 688.

The gastric juice contains hydrochloric acid, as may be seen from the above analysis. This acid renders the ptyalin of the saliva inactive as soon as the food is acted upon by the gastric juice. In addition to the acid there is also present a ferment called pepsin. It has been seen that the ptyalin changes starch to sugar, but pepsin changes the albuminoids into a peculiar class of substances called peptones.

Albuminoids and peptones differ very little in their chemical composition, and the following analyses will give a fair representation of these bodies.

	PER CENT	
Carbon	51.5	54.5
Hydrogen	6.9	7.3
Oxygen	20.9	23.5
Sulphur	.3	2 0
Nitrogen	15 2	17.0

The action of the gastric juice is largely that of changing the insoluble albuminoids to the soluble substances, or in other words, peptones, and from the analysis we find that there is little or no change in the chemical composition.

After the action of the gastric juice in the stomach, the food material passes to the intestines, here a secretion of the pancreas, called the pancreatic juice, acts upon it. The pancreatic juice is alkaline, and the action of the gastric juice ceases its action, as its action is only carried on in the presence of acids.

The pancreatic juice on analysis is found to be composed as follows:

	Dog.	Horse.
Water	980.45	982 50
Solids	19.55	17.50
Organic solids	12.71	8.88
Ash	6.84	8.62
Sodium	3.31	......
Chlorides	3.43	......
Phosphates	.09	......
Magnesium	.01	......

In the organic solids present in the pancreatic juice there are present three ferments, each of which take an active part in changing the food which has not been acted upon by the ptyalin and pepsin. These ferments are as follows:

I. Trypsin, changes proteids or albuminoids to peptones and amido acids.

II. Amylopsin changes starch to sugar.

III. Steapsin, a fat-decomposing ferment, changes fats into glycerin and fatty acids.

The bile also aids in the preparation of the fats for digestion.

The food, after being prepared by the action of ferments, is absorbed by certain vessels in the intestines, and ultimately becomes a part of the animal body.

In the process of digestion it has been seen that nature provides for the preparation of two classes of substances that are needed for repairing the waste of the animal body. These two classes are (1) those substances containing nitrogen, or flesh-producing substances, and (2) the carbohydrates, or heat-producing substances. If nature, then, requires that the animal be furnished with these two classes of foods in order that the body may continue in health, it would be naturally expected that these substances should be furnished in an intelligent manner and meet the demands made by nature upon the animal. The feeding to an animal of a substance containing an excessive amount of carbohydrates will probably lead to the injury of the organs by overwork, which nature has designed to govern and keep the animal machine in a healthy condition. The use of foods containing a much larger quantity of protein will probably result in the injury to the organs that control other parts of the animal machine.

It may be of interest to note that the food material as it is absorbed by the vessels of the intestines passes into the blood and is carried to the liver. The liver is one of the most important organs that care for the healthy condition of the body. Should the blood containing the digested food material contain an excessive amount of carbohydrates, the liver stores up these substances for some future time when the body will need them, and then they are given up again to the blood, so that the body may continue to be nourished. In a second capacity the liver acts as the control organ in preventing any poisonous products, which may be formed during any fermentation process that may have taken place in the digestive tract, from entering the circulating blood system and thus causing abnormal conditions. If these poisonous substances should pass through the vessels of the intestines they are separated and returned again to the intestines to be thrown off from the body as other impurities. The kidneys are also of great value in the sense that they keep the blood in a pure condition in their action of separating the impure substances that have

become part of the blood as the result of the breaking down of the food materials and tissues in the body, or in other words, the residue or ashes of muscular action. A large or an excessive amount of protein in the food material has a tendency to require an extra effort on the part of the kidneys to throw off from the body the resulting residues.

The study of the food material naturally divides itself under two considerations:

I. The amount of protein and of carbohydrates necessary for the animal, and the correct proportion of these two classes which will result in keeping the animal in the most healthy condition.

II. The use of an excess of one class of food material over the correct amount necessary results not only in an injury to the animal, but is largely a loss to the person feeding under such conditions.

The inorganic part of the food material supplies certain demands made by the growth and maintenance of the animal; for example, calcium phosphate supplies the material forming the bone substance. Salt furnishes the supply of hydrochloric acid in the gastric juice and aids in the digestion of food by the pepsin, and iron aids in blood formation.

The object of digestion is a process designed by nature to prepare the food material so that it can be readily absorbed by the animal. We may, as a means of illustration, compare the changes that take place during digestion to the process of some manufacturing plant where the food is crushed and ground by the teeth, the starch changed to sugar, the albuminoids which are insoluble rendered to soluble, or in other words, changed to peptones, and then as a final process the material is subjected to the combined action of a number of agencies which prevent any waste in the material intended for nourishing the animal.

The amount of food necessary for certain animals and the relative proportions of protein and the carbohydrates and fats has been the subject of a great number of investigations, and is a valuable field for study. Dr. Emil Wolff originated a table of feeding standards which has been widely used. The table is as follows:

PER DAY AND PER 1,000 POUNDS, LIVE WEIGHT.

	DIGESTIVE NUTRITIVE SUBSTANCES.			FUEL VALUE
	Protein, pounds.	Carbohydrates, pounds.	Fat, pounds.	Calories.
Oxen at rest in stall	0.7	8.0	0.15	16,815
Wool sheep:				
Coarser breeds	1.2	10.3	0.20	22,234
Finer breeds	1.5	11.4	0.25	25,049
Oxen:				
Moderately worked	1.6	11.3	0.30	25,260
Heavily worked	2.4	13.2	0.50	31,126
Horses:				
Moderately worked	1.8	11.2	0.60	26,712
Heavily worked	2.8	13.4	0.80	33,508
Milch cows	2.5	12.5	0.40	29,588
Fattening oxen:				
First period	2.5	15.0	0.50	35,660
Second period	3.0	14.8	0.70	36,062
Third period	2.7	14.8	0.60	35,082
Fattening sheep:				
First period	3.0	15.2	0 50	35,962
Second period	3.5	14.4	0 60	35,826
Fattening swine:				
First period	5.0	27.5		60,450
Second period	4.0	24.0		52,080
Third period	2.7	17.5		......

PER HEAD AND PER DAY.

	Age.	Average live weight per head.	DIGESTIBLE, NUTRITIVE SUBSTANCES.			Fuel valve.
			Protein	Carbo-hydr't's	Fat.	
	Months	Pounds.	Pounds.	Pounds.	Pounds.	Calories.
Growing cattle	2- 3	150	0.6	2.1	0.30	6,288
	3- 6	300	1.0	4.1	0.30	10,752
	6-12	500	1.3	6.8	0.30	16,332
	12-18	700	1.4	9.1	0.28	30,712
	18-24	850	1.4	10.3	0.26	22,859
Growing sheep	5- 6	56	0.18	0.87	0.045	2,143
	6- 8	67	0.17	0 85	0.040	2,066
	8-11	75	0.16	0.85	0.037	2,035
	11-15	82	0.14	0.89	0.032	2,050
	15-20	85	0.12	0.88	0.025	1,956
Growing fat swine	2- 3	50	0.38	1.50		3,497
	3- 5	100	0.50	2.50		5,580
	5- 6	125	0.54	2.96		6,510
	6- 8	170	0.58	3.47		7,633
	8-12	250	0.62	4.05		8,686

The above tables have been modified as the result of experience in feeding animals. The changes which have been made may be seen in the following tables, which are the original Wolff tables modified by Dr. Lehmann.

TABLE I.—FEEDING STANDARDS FOR FARM ANIMALS.

(Per day per 1,000 pounds, live weight.)

	Total dry substance.	NUTRITIVE (DIGESTIBLE) SUBSTANCES. Crude protein.	Carbohydrates	Fat ether extract.	Total nutritive substances.	Nutritive ratio.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
1. Oxen at rest in stall	18	0.7	8.0	0.1	8.9	1:11.8
Oxen slightly worked	22	1.4	10.0	0.3	12.1	1: 7.7
Oxen moderately worked	25	2.0	11.5	0.5	14.7	1: 6.5
Oxen heavily worked	28	2.8	13.0	0.8	17.7	1: 5.3
2. Fattening steers, 1st period	30	2.5	15.0	0.5	18.7	1: 6.5
Fattening steers, 2d period	30	3.0	14.5	0.7	19.2	1: 5.4
Fattening steers, 3d period	26	2.7	15.0	0.7	19.4	1: 6.2
3. Milch cows, daily milk yield, 11 lbs	25	1.6	10.0	0.3	12.8	1: 6.7
Milch cows, daily milk yield, 16.5 lbs	27	2.0	11.0	0.4	14.0	1: 6.0
Milch cows, daily milk yield, 22 lbs	29	2.5	13.0	0.5	16.7	1: 5.7
Milch cows, daily milk yield, 27.5 lbs	32	3.3	13.0	0.8	18.2	1: 4.5
4. Sheep, coarse wool	20	1.2	10.5	0.2	12.8	1: 9.1
Sheep, fine wool	23	1.5	12.0	0.3	14.2	1: 8.5
5. Breeding ewes, with lambs	25	2.9	15.0	0.5	19.1	1: 5.6
6. Fattening sheep, 1st period	30	3.0	15.0	0.5	19.2	1: 5.4
Fattening sheep, 2d period	28	3.5	14.5	0.6	19.4	1: 4.5
7. Horses, light work	20	1.5	9.5	0.4	12.0	1: 7.0
Horses, medium work	24	2.0	11.0	0.6	14.5	1: 6.2
Horses, heavy work	26	2.5	13.3	0.8	17.7	1: 6.0
8. Brood sows	22	2.5	15.5	0.4	19.0	1: 6.6
9. Fattening swine, 1st period	36	4.5	25.0	0.7	31.2	1: 5.9
Fattening swine, 2d period	32	4.0	24.0	0.5	29.2	1: 6.3
Fattening swine, 3d period	25	2.7	18.0	0.4	22.0	1: 7.0

TABLE I.—CONTINUED.

	Age in months.	Av. live weight per head.	Total dry substance.	NUTRITIVE (DIGESTIBLE) SUBSTANCES. Crude protein.	Carbo-hydrates	Fat ether extract.	Total nutritive substance.	Nutritive ratio.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
10. Growing cattle............	2- 3	150	23	4.0	13.0	2.0	21 8	1: 4.5
(Dairy breeds.)	3- 6	300	24	3.0	12 8	1.0	18.2	1: 5.1
	6-12	500	27	2.0	12.5	0 5	15.7	1: 6.8
	12-18	700	26	1.8	12.5	0.4	15 3	1: 7.5
	18-24	900	26	1.5	12.0	0 3	14 2	1: 8.5
11. Growing cattle............	2- 3	160	23	4.2	13.0	2.0	20.0	1: 4.2
(Beef breeds.)	3- 6	330	24	3.5	12 8	1.5	19.9	1: 4.7
	6-12	550	25	2 5	13 2	0.7	17.4	1: 6.0
	12-18	750	24	2.0	13.5	0.5	15.7	1: 6.5
	18-24	950	24	1.8	12 0	0.4	14.8	1: 7.2
12. Growing sheep............	4- 6	60	25	3.4	15 4	0.7	20.5	1: 5.0
(Wool breeds.)	6- 8	75	25	2.8	13.8	0.6	18.0	1: 5.4
	8-11	80	23	2.1	11.5	0.5	14.8	1: 6.0
	11-15	90	22	1.8	11 2	0.4	14 0	1: 7.0
	15-20	100	22	1 5	10.8	0.3	13.0	1: 7.7
13. Growing sheep............	4- 6	60	26	4.4	15.5	0.9	22.1	1: 4.0
(Mutton breeds.)	6- 8	80	26	3 5	15 0	0.7	20 2	1: 4.8
	8-11	100	24	3.0	14.3	0.5	18.5	1: 5.2
	11-15	120	23	2 2	12 6	0.5	16.0	1: 6 3
	15-20	150	22	2 0	12.0	0.4	15 0	1: 6 5
14. Growing swine............	2- 3	50	44	7 6	28.0	1.0	38 0	1: 4.0
(Breeding stock.)	3- 5	100	35	5.0	23 1	0.8	30.0	1: 5.0
	5- 6	120	32	3.7	21.3	0.4	26.0	1: 6 0
	6- 8	200	28	2.8	18.7	0.3	22 2	1: 7.0
	8-12	250	25	2.1	15 3	0.2	17.9	1: 7.5
15. Growing, fattening swine.	2- 3	50	44	7.6	28.0	1 0	38.0	1: 4.0
	3- 5	100	35	5.0	23.1	0.8	30.0	1: 5 0
	5- 6	150	33	4 3	22.3	0.6	28.0	1: 5.5
	6- 8	200	30	3.6	20 5	0 4	25.1	1: 6.0
	9-12	300	26	3.0	18.3	0.3	22.0	1: 6.4

Naturally, in order to apply the standards as given in the above table, a thorough study of all the materials used for feeding purposes is necessary. Many of the stations have paid especial attention to this field of work, and the following tables are selected from Bul. 81 of Vermont experiment station.

TABLE II.—AVERAGE COMPOSITION OF FEEDING STUFFS.

FODDERS.	Number of analyses.	FOOD CONSTITUENTS.						Reference number.	FERTILIZING INGREDIENTS.		
		Water.	Crude ash.	Crude protein.	Crude fiber.	Nitrogen-free ext'ct	Ether ext'ct		Nitrogen.	Phosphoric acid.	Potash.
ROUGHAGES.											
Green fodders.											
Pasture grass	......	80.0	2.0	3.5	4.0	9.7	0.8	2	0.56	0.23	0.75
Timothy	56	61.6	2.1	3.1	11.8	20.2	1.2	1	0.50	0.26	0.76
Red Top	5	65.3	2.3	2.8	11.0	17.7	0.9	4	0.45	....	....
Kentucky bluegrass*	18	65.1	2.8	4.1	9.1	17.6	1.3	1	0.66	0.24	1.08
Rowen	4	70.1	2.4	4.5	7.6	13.7	1.7	5	0.72	0.15	0.55
Fodder corn	126	79.3	1.2	1.8	5.0	12.2	0.5	1	0.29	0.15	0.33
Sweet fodder corn	21	79.1	1.3	1.9	4.4	12.8	0.5	1	0.30	......	.....
Barley fodder	6	75.2	2.0	3.4	6.5	12.0	0.9	5	0.54	....	.....
Oat fodder	5	62.2	2.5	3.4	11.2	19.3	1.4	1	0.54	0.13	0.38
Rye fodder	7	76.6	1.8	2.6	11.6	6.8	0.6	1	0.42	0.15	0.73
Hungarian	14	71.1	1.7	3.1	9.2	14.2	0.7	4	0.50	0.16	0.55
Oats and peas	9	78.7	1.7	3.5	6.0	9.1	1.0	5	0.56	0.12	0.54
Barley and peas	9	79.4	1.8	3.7	5.2	9.1	0.8	5	0.59	.....	.....
Red clover	43	70.8	2.1	4.4	8.1	13.5	1.1	1	0.70	0.13	0.46
Alsike clover	4	74.8	2.0	3.9	7.4	11.0	0.9	1	0.62	0.11	0.20
Clover rowen	5	75.0	2.1	4.6	6.2	11.0	1.1	5	0.74	......	.....
Hays and dry fodders.											
Mixed hay	126	15.3	5.5	7.4	27.2	42.1	2.5	4	1.18	0.27	1.55
Timothy	68	13.2	4.4	5.9	29.0	45.0	2.5	1	0.94	0.53	0.90
Red Top	9	8.9	5.2	7.9	28.6	47.5	1.9	1	1.26	0.36	1.02
Kentucky bluegrass*	8	26.1	6.7	6.1	24.1	33.7	3.3	1	0.98	0.40	1.57
Rowen, mixed	23	16.6	6.8	11.6	22.5	39.4	3.1	1,3	1.86	0.43	1.49
Rowen, fine	15	13.1	6.5	14.0	24.4	38.3	3.7	5	2.24	....	.....
Corn fodder	35	42.2	2.7	4.5	14.3	34.7	1.6	1	0.72	0.54	0.89
Corn stover	60	40.1	3.4	3.8	19.8	31.8	1.1	1	0.61	0.29	1.40
Oat hay	6	8.9	6.2	7.6	29.3	45.1	2.9	2	1.22	0.50	0.80
Oat and pea hay	8	11.5	6.6	14.8	24.9	38.9	3.3	5	2.37	0.51	2.25
Hungarian	23	16.5	5.6	8.2	22.6	43.9	3.2	5	1.31	0.35	1.30
Red clover hay	38	15.3	6.2	12.3	24.8	38.1	3.3	1	1.97	0.38	2.20
Alsike clover hay	9	9.7	8.3	12.8	25.6	40.7	2.9	1	2.05	0.67	2.23
Clover rowen hay	1	8.3	7.1	13.1	31.8	37.9	3.3	7a	2.10	.....	.....
Barley straw	97	14.2	5.7	3.5	36.0	39.0	1.5	6	0.56	0.30	2.09
Oat straw	12	9.2	5.1	4.0	37.0	42.4	2.3	1	0.64	0.20	1.24
Wheat straw	7	9.6	4.2	3.4	38.1	43.4	1.3	1	0.54	0.12	0.51
Rye straw	7	7.1	3.2	3.0	38.9	46.6	1.2	1	0.48	0.28	0.79
Silages and roots.											
Corn silage (mature corn)	49	73.7	1.6	2.2	6.5	15.1	0.9	8	0.35	0.10	0.40
do (immature corn)	99	79.1	1.4	1.7	6.0	11.0	0.8	1	0.27	0.10	0.40
do (ears plucked off)	6	80.7	1.8	1.8	5.6	9.5	0.6	8	0.29	0.11	0.45
Clover silage	5	72.0	2.6	4.2	8.4	11.6	1.2	1	0.67	....	.....
Potatoes	12	78.9	1.0	2.1	0.6	17.3	0.1	1	0.34	0.12	0.46
Beets	9	88.5	1.0	1.5	0.9	8.0	0.1	1	0.24	0.09	0.44
Sugar beets	19	86.5	0.9	1.8	0.9	9.8	0.1	1	0.29	0.10	0.48
Carrots	8	88.6	1.0	1.1	1.3	7.6	0.4	1	0.18	0.09	0.51
Mangel-wurtzels	9	90.9	1.1	1.4	0.9	5.5	0.2	1	0.22	0.09	0.38
Rutabagas	4	88.6	1.2	1.2	1.3	7.5	0.2	1	0.19	0.12	0.49
Turnips	3	90.5	0.8	1.1	1.2	6.2	0.2	1	0.18	0.10	0.39

* June grass.

TABLE II—CONTINUED.

FODDERS.	Number of analyses.	FOOD CONSTITUENTS. Water.	Crude ash.	Crude protein.	Crude fiber.	Nitrogen-free ext'ct	Ether ext'ct	Reference number.	FERTILIZING INGREDIENTS. Nitrogen.	Phosphoric acid.	Potash.
Miscellaneous.											
Apples	3	80.7	0.4	0.7	1.2	16.6	0.4	....	0.11	0.01	0.19
Apple pomace	7	76.7	0.5	1.4	3.9	16.2	1.3	1	0.23	0.02	0.13
Pumpkins	....	90.9	0.5	1.3	1.7	5.2	0.4	2	0.21	0.16	0.09
Skimmilk	7	90.6	0.7	3.1	.....	5.3	0.3	4	0.50	0.20	0.19
Buttermilk	85	90.1	0.7	4.0	......	4.0	1.1	6	0.64	0.17	0.16
Whey	46	93.8	0.4	0.6	......	5.1	0.1	6	0.10	0.14	0.18
CONCENTRATES.											
Grains and by-products.											
Corn meal	77	15.0	1.4	9.2	1.9	68.7	3.8	1	1.47	0.63	0.40
Corn and cob meal	7	15.1	1.5	8.5	6.6	64.8	3.5	1	1.36	0.57	0.47
Oats	30	11.0	3.0	11.8	9.5	59.7	5.0	1	1.89	0.82	0.62
Provender (⅓corn ⅓oats)	....	13.0	2.2	10.5	5.7	64.2	4.4	..	1.68	0.73	0.51
do (as sold in NewEng)	13-38	11.6	2.6	9.3	8.0	64.7	3.8	9,8	1.49	.....	.....
Oat hulls	1	7.3	6.7	3.3	29.7	52.1	1.0	2	0.53	.....	.....
Quaker dairy feed	5-24	8.3	5.0	13.4	16.8	52.8	3.7	9,8	2.14	0.83	0.70
H. O. dairy feed	6-20	8.8	3.8	18.9	13.3	51.2	4.0	9,8	3.02	......	.....
Victor corn and oat feed	4-64	9.9	4.0	8.9	12.8	60.6	3.8	9,8	1.42	....	....
H. O. horse feed	9-24	9.9	3.1	12.4	10.1	60.4	4.1	9,8	1.98	.....	.....
Barley	10	10.9	2.4	12.4	2.7	69.8	1.8	1	1.98	0.79	0.48
Barley screenings	2	12.2	3.6	12.3	7.3	61.8	2.8	1	1.97	...	.....
Wheat	310	10.5	1.8	11.9	1.8	71.9	2.1	1	1.90	0.80	0.50
Wheat bran	88	11.9	5.8	15.4	9.0	53.9	4.0	1	2.46	2.80	1.61
Wheat middlings	32	12.1	3.3	15.6	4.6	60.4	4.0	1	2.50	0.95	0.63
Wheat screenings	10	11.6	2.9	12.5	4.9	65.1	3.0	1	2.00	.....	....
Mixed (wheat) feed	48	10.8	5.5	16.8	7.4	54.8	4.7	9	2.69	......	.....
Reddog flour	1	9.0	3.8	23.2	1.9	57.4	5.7	8	3.55	..	.....
Rye	6	11.6	1.9	10.6	1.7	72.5	1.7	1	1.70	0.82	0.54
Rye bran	7	11.6	3.6	14.7	30.5	63.8	2.8	1	2.35	2.28	1.40
Buckwheat	8	12.6	2.0	10.0	8.7	64.5	2.2	1	1.60	0.44	0.21
Buckwheat hulls	2	11.6	2.2	5.6	35.0	43.4	1.6	1	0.90	0.07	0.52
Buckwheat bran	2	10.5	3.0	12.4	31.9	38.8	3.3	2	1.98	0.68	0.75
Buckwheat middlings	6	11.5	4.5	27.5	4.2	45.3	7.0	1,8	4.40	1.95	0.99
Cottonseed meal	10-249	8.3	6.9	45.4	5.5	23.7	11.2	9,8	7.26	2.88	1.87
Cottonseed feed	8	11.7	3.1	12.0	31.0	39.1	3.1	7b	1.92	0.85	1.38
Cottonseed hulls	20	11.1	2.8	4.2	46.3	33.4	2.2	4	0.67	0.25	1.02
Linseed meal (old proc's)	8-31	9.9	5.8	34.6	8.1	34.1	7.5	9,8	5.54	1.66	1.37
Linseed meal (new proc's)	4-48	10.7	5.6	38.1	8.2	34.8	2.6	9,8	6.10	1.83	1.39
Flax meal	2	11.4	5.1	37.8	8.8	33.4	3.5	9,8	6.05	1.80	1.31
Gluten meal (Chicago)	5-98	12.3	1.2	36.5	1.4	45.8	2.7	9,8	5.84	0.39	0.06
Gluten meal (Cream)	4-83	10.1	0.8	33.7	1.7	51.1	2.6	9,8	5.39	0.36	0.20
Gluten meal (King)	1-17	7.4	0.5	33.7	1.2	52.6	4.6	9,8	5.39	0.36	0.07
Gluten feed (Buffalo)	6-43	9.6	2.3	27.1	6.7	51.1	3.2	9,8	4.34	0.83	0.42
Gluten feed (Diamond or Rockford)	5-32	8.9	0.8	23.6	6.6	56.6	3.5	9,8	3.78	0.30	0.06
Hominy chop	8-20	8.4	2.6	11.3	4.9	64.9	7.9	9.8	1.81	0.98	0.49
Starch feed, wet	12	65.4	0.3	6.1	3.1	22.0	3.1	1	0.98	....	....
Dried brewers' grains	3	8.2	3.6	19.9	11.0	51.7	5.6	1	3.18	1.03	0.09
Atlas gluten meal	6	8.3	1.8	33.7	11.5	32.1	12.6	3,8	5.30	0.65	0.14
Malt sprouts	4	10.2	5.7	23.2	10.7	48.5	1.7	1	3.71	1.43	1.63
Pea meal	2	10.5	2.6	20.2	14.4	51.1	1.2	1	3.23	0.82	0.99

TABLE III—AMERICAN DIGESTION COEFFICIENTS; DIGESTIBLE INGREDIENTS OF AMERICAN FEEDING STUFFS.

FODDERS.	Number of trials.	Digestion coefficients. Dry matter.	Organic matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Percentage of digestible ingredients. Dry matter.	Organic matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
ROUGHAGES.													
Green fodders.													
Pasture grass	1	69	70	66	74	73	55	18.8	12.6	2.8	3.0	7.1	0.4
Timothy	1	64	66	48	56	66	53	24.6	24.0	1.5	6.6	12.2	0.6
Red top	..							23.2	21.4	1.3	6.2	11.7	0.5
Kentucky blue grass†	..							22.8	21.2	2.0	5.1	11.6	0.7
Rowen	2	66	67	70	63	70	54	19.4	18.4	3.3	4.6	9.6	0.9
Fodder corn	14	68	70	60	60	74	74	14.1	13.7	1.1	3.0	9.0	0.4
Sweet fodder corn	6	71	72	64	63	77	76	14.8	14.1	1.2	2.6	9.9	0.4
Barley fodder	2	65	68	72	61	71	60	16.4	15.5	2.4	4.0	8.6	0.5
Oat fodder	2	60	61	73	63	63	60	22.7	21.5	2.4	5.9	12.0	1.0
Rye fodder	1	73	75	79	79	70	75	17.1	16.2	2.1	9.2	4.8	0.6
Hungarian	3	67	69	64	71	68	66	19.4	18.9	2.0	6.5	9.7	0.5
Oats and peas	4	65	67	76	60	68	68	13.8	13.1	2.7	3.6	6.2	0.7
Barley and peas	1	63	60	77	44	61	60	10.9	11.9	2.8	2.3	6.6	0.5
Red clover	1	66	68	67	53	78	65	19.3	18.4	2.9	4.3	10.5	0.7
Alsike clover	..							16.6	15.6	2.6	3.9	8.6	0.6
Clover rowen	1	59	61	66	68	65	61	14.8	14.0	2.9	3.3	7.2	0.7
Hays and dry fodders.													
Mixed hay	5	57	59	59	60	60	49	48.3	46.7	4.4	16.3	24.8	1.2
Timothy	17	57	59	47	58	62	52	49.5	48.6	2.8	15.4	27.9	1.3
Red top	2	60	61	61	61	62	51	54.7	51.4	4.8	17.4	29.5	1.0
Kentucky blue grass†	..							44.2	41.0	2.7	14.7	20.9	1.7
Rowen, mixed	2	64	66	69	67	65	47	58.4	50.6	8.0	16.1	26.0	1.5
Rowen, fine								55.4	53.1	9.7	16.3	26.2	1.7
Corn fodder	10	69	71	56	56	72	74	39.3	38.1	2.5	8.0	25.0	1.3
Corn stover	5	57	59	36	64	66	70	34.1	33.3	1.4	12.7	18.4	0.8
Oat hay	1	49	50	54	44	52	63	43.9	41.7	4.1	12.9	23.6	1.3
Oat and pea hay	..							57.5	54.9	11.2	14.9	26.5	2.2
Hungarian	1	65	65	60	68	67	64	54.3	51.4	4.9	15.4	29.4	2.0
Red clover hay	6	57	60	58	54	64	55	49.2	47.1	7.1	13.4	24.4	1.8
Alsike clover hay	2	62	63	66	54	71	60	56.0	51.7	8.4	15.8	26.9	1.6
Clover rowen hay	2	58	59	65	47	64	60	53.2	49.9	8.6	14.7	23.9	1.4
Barley straw*	5	54		20	56	54	42	45.5	42.6	0.7	20.2	21.1	0.6
Oat straw	1	50	52	*30	58	58	28	45.4	44.6	1.2	21.5	22.5	0.9
Wheat straw*	7	43		11	52	35	31	38.9	37.1	0.4	19.8	16.5	0.4
Rye straw*	9	46		21	60	27	33	42.7	40.4	0.6	23.2	17.2	0.4
Silages and roots.													
Corn silage (mature corn)	10	71	74	56	70	76	83	18.7	18.8	1.2	4.6	11.5	0.7
Corn silage (immature corn)	13	66	67	51	71	67	80	13.8	13.1	0.9	4.3	7.4	0.6
Corn silage (ears plucked off)	..	57	59	38	64	58	70	11.0	10.2	0.6	3.6	5.5	0.4
Clover silage	..							16.2	15.0	2.7	3.9	7.8	0.7
Potatoes	1	76	77	45	....	90	13	16.0	15.5	0.9		15.6	....
Beets								10.9	10.4	1.4	0.9	8.0	0.1
Sugar beets	1	95	99	91	100	100	50	12.8	12.6	1.5	0.9	9.8	0.1
Carrots	..							10.6	10.0	1.0	1.3	7.4	0.4
Mangel-wurtzels	1	79	85	75	48	71	....	7.2	6.8	1.1	0.4	5.0	....
Rutabagas	1	87	91	80	74	95	84	9.9	9.3	1.0	1.0	7.1	0.2
Turnips	1	93	95	90	100	97	68	8.8	8.4	1.0	1.2	6.0	0.2
Miscellaneous.													
Apples	..												
Apple pomace	..												
Pumpkins	..												
Skimmilk*† (separator)	..							9.2	8.5	2.9	..	5.2	0.3
Buttermilk*†	..	98	....	94		98	100	9.7	9.0	3.8	....	3.9	1.1
Whey*†	..							6.1	5.7	0.8	....	5.0	0.1

TABLE III—AMERICAN DIGESTION COEFFICIENTS; DIGESTIBLE INGREDIENTS OF AMERICAN FEEDING STUFFS—*Continued.*

FODDERS.	Number of trials	Digestion coefficients. Dry matter.	Organic matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Percentage of digestible ingredients. Dry matter.	Organic matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
CONCENTRATES.													
Grains and byproducts.													
Corn meal	5	89	90	68	....	95	92	75.7	75.2	6.3	....	65.3	3.5
Corn and cob meal	2	79	80	56	46	88	84	67.1	66.7	4.8	3.0	57.0	2.9
Oats*	39	70	....	78	20	76	83	62.3	60.2	9.2	1.9	45.4	4.2
Provender (½ corn, ½ oats)	..	80	....	78	10	86	88	69.6	67.8	7.7	0.6	55.2	3.9
Provender (as sold in New Eng)	..	[10]	...	....	....	....	....	70.7	68.6	6.8	0.8	55.6	3.3
Oat hulls	..	[11]	...	....	....	....	....	61.9	60.2	2.6	5.9	39.6	0.8
Quaker dairy feed	1	62	65	81	43	67	89	56.9	56.4	10.9	7.2	35.4	3.3
H. O. dairy feed	1	65	68	78	41	70	86	59.3	59.4	14.7	5.5	35.8	3.4
Victor corn and oat feed	1	75	77	71	48	84	87	67.6	66.3	6.3	6.1	50.3	3.3
H. O. horse feed	1	70	73	74	35	79	84	63.1	63.5	9.2	3.5	47.7	3.4
Barley*	4	86	....	70	50	92	89	76.6	74.6	8.7	1.4	64.2	1.6
Barley screenings	..	[12]	....	....	....	....	....	75.5	72.4	8.6	3.7	56.9	2.5
Wheat	..	[9]	....	....	....	....	....	....	....	....	....	....	....
Wheat bran	7	62	66	78	29	69	68	54.6	54.3	12.0	2.6	37.2	2.7
Wheat middlings	3	75	79	80	33	81	86	65.9	66.8	12.5	1.5	48.9	3.4
Wheat screenings	..	[13]	...	....	....	....	....	54.8	56.4	9.8	1.4	41.9	2.0
Mixed (wheat) feed	..	[14]	...	....	....	....	....	61.5	61.1	13.3	2.3	41.1	3.6
Red dog flour	..	[15]	...	....	....	....	....	68.3	68.9	17.8	0.6	46.5	4.9
Rye	1	87	89	84	....	92	64	76.9	77.0	8.9	....	66.7	1.1
Rye bran	..	[16]	...	....	....	....	....	76.9	75.5	12.3	....	58.7	1.8
Buckwheat	..	[9]	...	....	....	....	....	....	....	....	....	....	....
Buckwheat hulls	..	[9]	...	....	....	....	....	....	....	....	....	....	....
Buckwheat bran	..	[9]	...	....	....	....	....	....	....	....	....	....	....
Buckwheat middlings	..	[9]	...	....	....	....	....	....	....	....	....	....	....
Cotton seed meal	5	74	76	88	56	61	93	67.9	64.4	40.0	3.1	13.8	10.4
Cotton seed feed	..	[17]	...	....	....	....	....	58.3	57.1	7.9	16.1	21.9	2.8
Cotton seed hulls	3	40	41	....	40	41	86	35.6	35.3	....	18.5	13.7	1.9
Linseed meal (old process)	1	79	81	89	57	78	89	71.2	68.3	30.8	4.6	26.6	6.7
Linseed meal (new process)	2	79	82	85	80	86	97	70.5	68.6	32.4	6.6	29.9	2.5
Flax meal	..	[18]	....	....	....	....	....	70.0	68.5	32.1	7.0	28.7	3.4
Gluten meal (Chicago)	..	....	....	....	....	....	....	78.9	77.8	32.1	....	41.2	2.5
Gluten meal (Cream)	4	90	90	88	....	90	94	80.9	80.2	29.7	....	46.0	2.4
Gluten meal (King)	..	....	....	....	....	....	....	83.3	83.9	29.7	....	47.3	4.3
Gluten meal (Buffalo)	..	....	....	....	....	....	....	77.7	76.6	23.3	5.2	45.5	2.7
Gluten meal (Diamond or Rockford)	1	86	87	86	78	89	84	78.3	78.6	20.3	5.1	50.4	2.9
Hominy chop	1	90	93	77	82	95	81	82.4	83.8	8.7	4.0	61.7	6.4
Starch feed, wet	..	[19]	....	....	....	....	....	31.1	30.9	5.4	....	19.8	2.9
Dried brewers grains	1	62	65	79	53	58	91	56.9	57.3	15.7	5.8	30.0	5.1
Atlas gluten meal	1	80	83	73	100	85	91	73.4	74.6	21.6	11.5	27.3	11.5
Malt sprouts	1	67	67	80	33	68	100	60.2	56.3	18.6	3.5	33.0	1.7
Pea meal	1	87	88	83	28	94	55	77.9	76.5	16.8	8.7	48.0	0.7

[1] Assume timothy.
[2] Assume red clover.
[3] Assume red top.
[4] Assume rowen mixed.
[5] Assume green oats and peas.
* European coefficients, no American experiments published.
[6] Assume clover rowen hay.
[7] Assume sugar beets.
[8] Assume turnips.
[9] No basis for assumption.
[10] Assume provender.
[11] Assume oats.
[12] Assume barley.
† Digestion coefficients of whole milk.
[13] Assume bran.
[14] Assume mean of bran and middlings.
[15] Assume middlings.
[16] Assume rye.
[17] Assume ¾ meal, ¼ hulls.
[18] Assume new process linseed.
[19] Assume gluten meal.

TABLE IV—POUNDS OF TOTAL DRY MATTER, TOTAL ORGANIC MATTER AND DIGESTIBLE INGREDIENTS (protein and carbohydrates [including ether extract × 2.25]) in varying weights of fodders and feeds, being essentially a CONVENIENCE TABLE.

POUNDS OF FODDER.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.
GRASSES.	**PASTURE GRASS, 1:4 8.**				**TIMOTHY GRASS, 1:14.3.**				**RED TOP GRASS, 1:14.6.**			
2½	0 5	0 5	0 08	0.3	1 0	0.9	0.04	0.5	0.9	0 8	0.03	0 5
5	1 0	0.9	0.12	0.6	1.9	1 8	0.08	1.1	1.7	1.6	0.07	1.0
10	2.0	1.8	0.23	1.1	3 8	3.6	0.15	2.1	3.5	3 2	0.13	1.9
15	3 0	2.7	0.35	1.7	5 8	5 4	0.23	3 2	5.2	4.9	0.20	2 9
20	4.0	3.6	0.46	2.2	7.7	7.3	0.30	4.3	6.9	6.5	0.26	3.8
25	5.0	4.5	0.58	2.8	9.6	9 1	0.38	5.4	8.7	8.1	0 33	4.8
30	6.0	5.4	0.69	3.3	11 5	10.9	0 45	6.4	10 4	9.7	0.39	5 7
35	7 0	6.3	0.81	3 9	13.4	12 7	0.53	7 5	12 1	11.3	0.46	6.7
40	8 0	7.2	0.92	4 4	15.4	14.5	0.60	8.6	13.9	13 0	0.52	7.6
GRASSES.	**KENTUCKY BLUE GRASS, 1:9.2.**				**GREEN ROWEN, 1:5 1**				**GREEN FODDER CORN, 1:11 7.**			
2½	0.9	0.8	0 05	0.5	0 7	0.7	0.08	0.4	0.5	0.5	0.03	0.3
5	1 8	1.6	0.10	0 9	1.5	1.4	0 16	0.8	1.0	1.0	0.06	0.6
10	3.5	3.2	0.20	1 8	3.0	2 8	0.32	1.6	2 1	2.0	0.11	1.3
15	5.2	4 8	0.30	2 7	4 5	4.1	0.48	2 5	3.1	2.9	0.17	1.9
20	7.0	6.4	0.40	3.7	6.0	5.5	0 64	3.3	4 1	3.9	0.22	2.6
25	8 7	8 0	0 50	4.7	7 5	6 9	0.80	4.1	5 2	4.9	0 28	3.2
30	10.5	9.6	0.60	5.5	9 0	8.3	0.96	4.9	6.2	5.9	0.33	3.9
35	12.2	11.2	0.70	6.4	10.5	9.6	1 12	5 7	7 2	6 8	0.39	4.5
40	14.0	12.8	0 80	7.3	12 0	11.0	1.28	6.6	8.3	7.8	0 44	5.2
GREEN FODDERS.	**SWEET FODDER CORN, 1:11.3**				**GREEN BARLEY FODDER, 1:5.7.**				**GREEN OAT FODDER, 1:8 7.**			
2½	0.5	0.5	0 03	0 3	0 6	0.6	0.06	0.3	0.9	0.9	0.06	0.5
5	1.0	1.0	0 06	0.7	1.2	1.1	0.12	0.7	1.9	1 8	0.12	1.0
10	2 1	2.0	0.12	1.4	2.5	2.3	0.24	1 4	3.8	3.5	0.24	2.1
15	3.1	2.9	0.18	2.1	3 7	3.4	0 36	2 1	5 7	5.3	0 36	3.1
20	4 2	3.9	0.24	2 7	5.0	4.6	0.48	2.7	7.6	7.1	0.48	4 2
25	5.2	4 9	0.30	3.4	6.2	5.7	0 60	3 4	9 5	8.9	0.60	5.2
30	6.3	5.9	0 36	4 1	7.4	6 8	0.72	4.1	11 3	10.6	0.72	6 2
35	7.3	6.8	0.42	4 8	8.7	8.0	0.84	4 8	13.2	12.3	0.84	7.3
40	8 4	7.8	0.48	5.4	9.9	9 1	0.96	5.4	15.1	14.1	0 96	8 3
GREEN FODDERS.	**GREEN RYE FODDER, 1:7 2.**				**GREEN HUNGARIAN, 1:8.7.**				**OATS AND PEAS, 1:4.2.**			
2½	0.6	0.5	0.05	0.4	0.7	0 7	0.05	0 4	0.5	0.5	0.07	0.3
5	1.2	1.1	0.11	0.7	1.4	1 4	0 10	0.8	1.1	1.0	0.14	0.5
10	2.3	2.2	0 21	1 5	2 9	2 7	0.20	1.7	2.1	2 0	0.27	1.1
15	3.5	3.2	0.32	2.3	4 3	4 0	0.30	2.6	3.2	2.9	0.41	1.7
20	4.7	4.3	0.42	3.0	5.8	5.4	0.40	3.5	4 3	3.9	0.54	2 3
25	5.9	5.4	0.52	3.8	7.2	6.8	0.50	4 3	5.3	4.9	0.68	2.9
30	7.0	6.5	0.63	4.5	8.7	8.2	0.60	5.2	6.4	5 9	0 81	3.4
35	8.2	7.6	0.74	5.3	10.1	9.5	0 70	6.1	7 5	6 8	0.95	4.0
40	9 4	8.6	0.84	6.0	11 6	10 9	0.80	6.9	8.5	7.8	1.08	4 6
GREEN FODDERS	**BARLEY AND PEAS, 1:3.2.**				**RED CLOVER (green), 1:5.7.**				**ALSIKE CLOVER (green) 1:5 3.**			
2½	0 5	0.5	0.07	0.2	0.7	0.7	0.07	0.4	0 6	0.6	0.07	0.3
5	1.0	0 9	0.14	0.4	1.5	1 4	0 15	0 8	1.3	1 2	0.13	0.7
10	2.1	1 9	0.28	0.9	2 9	2.7	0.29	1.6	2.5	2 3	0 26	1.4
15	3.1	2 8	0.42	1.4	4.4	4.0	0 44	2 5	3.8	3.5	0 39	2.1
20	4.1	3.8	0.56	1.8	5.9	5 4	0 58	3.3	5.0	4 7	0.52	2.8
25	5.2	4 7	0.70	2 3	7.3	6 8	0.73	4.1	6 3	5 9	0.65	3.5
30	6 2	5.6	0.84	2.7	8.8	8.2	0 87	4.9	7.6	7.0	0.78	4.2
35	7.2	6 6	0.98	3.2	10.2	9 5	1 02	5.7	8.8	8.1	0.91	4.9
40	8.2	7 5	1 12	3.6	11.7	10.9	1 16	6 6	10.1	9 3	1.04	5.6

TABLE IV—POUNDS OF TOTAL DRY MATTER, TOTAL ORGANIC MATTER AND DIGESTIBLE INGREDIENTS—CONTINUED.

POUNDS OF FODDER.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.
GREEN FODDERS AND SILAGES.	GREEN CLOVER ROWEN, 1:4.2.				CORN SILAGE (mature), 1:14.6				CORN SILAGE (immature), 1:14.6			
2½	0.6	0.5	0.07	0.3	0.7	0.6	0.03	0.4	0.5	0.5	0.02	0.3
5	1.2	1.2	0.14	0.6	1.3	1.2	0.06	0.8	1.0	1.0	0.05	0.6
10	2.5	2.3	0.29	1.2	2.6	2.5	0.12	1.8	2.1	2.0	0.09	1.3
15	3.8	3.5	0.44	1.8	3.9	3.6	0.18	2.7	3.1	2.9	0.14	1.9
20	5.0	4.6	0.58	2.4	5.3	4.9	0.24	3.6	4.2	3.9	0.18	2.6
25	6.3	5.8	0.73	3.0	6.6	6.2	0.30	4.5	5.2	4.9	0.23	3.2
30	7.5	6.9	0.87	3.6	7.9	7.4	0.36	5.3	6.3	5.9	0.27	3.9
35	8.8	8.1	1.02	4.2	9.2	8.7	0.42	6.2	7.3	6.8	0.32	4.5
40	10.0	9.2	1.16	4.8	10.5	9.9	0.48	7.1	8.4	7.8	0.36	5.2
SILAGES, ETC.	CORN STOVER SILAGE, 1:16.6.				CLOVER SILAGE, 1:4.7.				POTATOES, 1:17.8.			
2½	0.5	0.4	0.03	0.3	0.7	0.6	0.07	0.3	0.5	0.5	0.02	0.4
5	1.0	0.9	0.06	0.5	1.4	1.3	0.14	0.6	1.1	1.0	0.05	0.8
10	1.9	1.8	0.06	1.0	2.8	2.5	0.27	1.3	2.1	2.0	0.09	1.6
15	2.9	2.6	0.09	1.5	4.2	3.8	0.41	1.9	3.2	3.0	0.14	2.3
20	3.9	3.5	0.12	2.0	5.6	5.1	0.54	2.6	4.2	4.0	0.18	3.1
25	4.8	4.4	0.15	2.5	7.0	6.4	0.68	3.2	5.3	5.0	0.23	3.9
30	5.8	5.3	0.18	3.0	8.4	7.6	0.81	3.9	6.3	6.0	0.27	4.7
35	6.8	6.1	0.21	3.5	9.8	8.9	0.95	4.5	7.4	7.0	0.32	5.4
40	7.7	7.0	0.24	4.0	11.2	10.2	1.08	5.1	8.4	8.0	0.36	6.2
ROOTS.	BEETS, 1:6.5.				SUGAR BEETS, 1:6.8.				CARROTS, 1:9.6.			
2½	0.3	0.3	0.04	0.2	0.3	0.3	0.04	0.3	0.3	0.3	0.03	0.2
5	0.6	0.5	0.07	0.5	0.7	0.6	0.08	0.5	0.5	0.5	0.05	0.5
10	1.2	1.1	0.14	0.9	1.4	1.3	0.16	1.1	1.1	1.0	0.10	1.0
15	1.7	1.6	0.21	1.4	2.0	1.9	0.24	1.7	1.6	1.6	0.15	1.4
20	2.3	2.1	0.28	1.8	2.7	2.5	0.32	2.2	2.3	2.1	0.20	1.9
25	2.9	2.6	0.35	2.3	3.4	3.1	0.40	2.7	2.9	2.6	0.25	2.4
30	3.5	3.1	0.42	2.7	4.1	3.8	0.48	3.3	3.4	3.1	0.30	2.9
35	4.0	3.7	0.49	3.2	4.7	4.4	0.56	3.8	4.0	3.6	0.35	3.4
40	4.6	4.2	0.56	3.6	5.4	5.0	0.64	4.4	4.6	4.2	0.40	3.8
ROOTS.	MANGEL WURTZELS, 1:4.9.				RUTABAGAS 1:8.6.				TURNIPS, 1:7.7.			
2½	0.2	0.2	0.03	0.1	0.3	0.3	0.03	0.2	0.3	0.2	0.03	0.2
5	0.4	0.4	0.06	0.3	0.5	0.5	0.05	0.4	0.5	0.4	0.05	0.4
10	0.9	0.8	0.11	0.5	1.1	1.0	0.10	0.9	1.0	0.9	0.10	0.8
15	1.4	1.2	0.17	0.8	1.6	1.6	0.15	1.3	1.4	1.3	0.15	1.2
20	1.8	1.6	0.22	1.1	2.3	2.0	0.20	1.7	1.9	1.7	0.20	1.5
25	2.3	2.0	0.28	1.4	2.9	2.6	[illegible]	2.2	2.4	2.2	0.25	1.9
30	2.7	2.4	0.33	1.6	3.4	3.1	0.30	2.6	2.9	2.6	0.30	2.3
35	3.2	2.8	0.39	1.9	4.0	3.6	0.35	3.0	3.3	3.0	0.35	2.7
40	3.6	3.2	0.44	2.2	4.6	4.1	0.40	3.4	3.8	3.5	0.40	3.1
MILK.	SKIM MILK, 1:2.0.				BUTTERMILK, 1:1.7.				WHEY, 1:6.7.			
2½	0.2	0.2	0.07	0.1	0.2	0.2	0.10	0.2	0.3	0.1	0.03	0.1
5	0.5	0.4	0.15	0.3	0.5	0.5	0.19	0.3	0.3	0.3	0.03	0.3
10	0.9	0.9	0.29	0.6	1.0	0.9	0.38	0.6	0.6	0.6	0.06	0.5
15	1.4	1.3	0.44	0.9	1.5	1.4	0.57	1.0	0.9	0.8	0.09	0.8
20	1.9	1.7	0.58	1.2	2.0	1.8	0.76	1.3	1.2	1.2	0.12	1.0
25	2.4	2.2	0.73	1.5	2.5	2.3	0.95	1.6	1.5	1.5	0.15	1.3
30	2.8	2.6	0.87	1.8	3.0	2.8	1.14	1.9	1.9	1.8	0.18	1.6
35	3.3	3.0	1.02	2.1	3.5	3.2	1.33	2.3	2.2	2.0	0.21	1.8
40	3.7	3.5	1.16	2.4	4.0	3.7	1.52	2.6	2.5	2.3	0.24	2.1

TABLE IV—POUNDS OF TOTAL DRY MATTER, TOTAL ORGANIC MATTER AND DIGESTIBLE INGREDIENTS—CONTINUED.

POUNDS OF FODDER.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.
HAYS.	**MIXED HAY, 1:10.0.**				**TIMOTHY HAY, 1:16.5**				**RED TOP HAY, 1:10.3.**			
2½	2.1	2.0	0.11	1.1	2.2	2.1	0.07	1.2	2.3	2.1	0.12	1.2
5	4.2	4.0	0.22	2.2	4.3	4.1	0.14	2.4	4.6	4.3	0.24	2.4
7½	6.4	5.9	0.33	3.3	6.5	6.2	0.21	3.5	6.8	6.4	0.36	3.6
10	8.5	7.9	0.44	4.4	8.7	8.2	0.28	4.6	9.1	8.6	0.48	4.9
12½	10.6	9.9	0.55	5.5	10.9	10.3	0.35	5.8	11.4	10.7	0.60	6.2
15	12.7	11.9	0.66	6.6	13.0	12.4	0.42	6.9	13.9	12.9	0.72	7.4
17½	14.8	13.9	0.77	7.7	15.2	14.4	0.49	8.1	16.0	15.0	0.84	8.6
20	16.9	15.8	0.88	8.8	17.4	16.5	0.56	9.2	18.2	17.2	0.96	9.8
25	21.2	19.8	1.10	11.0	21.7	20.6	0.70	11.6	22.8	21.5	1.20	12.3
HAYS.	**KENTUCKY BLUE GRASS HAY, 1:10.6.**				**ROWEN HAY (mixed), 1:5.6**				**ROWEN HAY (fine), 1:4.7.**			
2½	1.9	1.7	0.09	1.0	2.1	1.9	0.20	1.1	2.2	2.0	0.24	1.1
5	3.7	3.4	0.19	2.0	4.2	3.8	0.40	2.3	4.3	4.0	0.49	2.3
7½	5.6	5.0	0.28	3.0	6.3	5.7	0.60	3.4	6.5	6.0	0.73	3.4
10	7.4	6.7	0.37	3.9	8.3	7.7	0.80	4.5	8.7	8.0	0.97	4.6
12½	9.2	8.4	0.46	4.9	10.4	9.5	1.0	5.6	10.9	10.0	1.21	5.7
15	11.1	10.1	0.56	5.9	12.5	11.4	1.20	6.7	13.0	12.1	1.46	6.8
17½	13.0	11.7	0.65	6.9	14.6	13.4	1.40	7.8	15.2	14.1	1.70	8.0
20	14.8	13.4	0.74	7.9	16.7	15.3	1.60	8.9	17.4	16.1	1.94	9.1
25	18.5	16.8	0.93	9.9	20.9	19.2	2.00	11.2	21.7	20.1	2.43	11.4
DRY FODDERS	**CORN FODDER, 1:14.3.**				**CORN STOVER, 1:23.6.**				**OAT HAY, 1:9.9.**			
2½	1.4	1.4	0.06	0.9	1.5	1.4	0.04	0.8	2.3	2.1	0.10	1.0
5	2.9	2.8	0.13	1.8	3.0	2.8	0.07	1.7	4.6	4.2	0.21	2.0
7½	4.3	4.1	0.19	2.7	4.5	4.2	0.11	2.5	6.8	6.4	0.31	3.0
10	5.8	5.5	0.25	3.6	6.0	5.7	0.14	3.3	9.1	8.5	0.41	4.0
12½	7.2	6.9	0.32	4.5	7.5	8.1	0.18	4.1	11.4	10.6	0.51	5.1
15	8.7	8.3	0.38	5.4	9.0	8.5	0.21	5.0	13.7	12.7	0.63	6.1
17½	10.1	9.6	0.44	6.2	10.5	9.9	0.25	5.8	16.0	14.9	0.73	7.1
20	11.6	11.0	0.50	7.1	12.0	11.3	0.28	6.6	18.2	17.0	0.82	8.1
25	14.5	13.8	0.63	8.9	15.0	14.1	0.35	8.3	22.8	21.2	1.03	10.2
HAYS.	**OAT AND PEA HAY, 1:4.1.**				**HUNGARIAN, 1:10.0.**				**RED CLOVER HAY, 1:5.9.**			
2½	2.2	2.0	0.28	1.2	2.1	1.9	0.12	1.2	2.1	2.0	0.18	1.0
5	4.4	4.1	0.56	2.3	4.2	3.9	0.25	2.4	4.2	3.9	0.36	2.1
7½	6.6	6.1	0.84	3.5	6.3	5.9	0.37	3.6	6.4	5.9	0.53	3.2
10	8.9	8.2	1.12	4.6	8.4	7.8	0.49	4.9	8.5	7.9	0.71	4.2
12½	11.1	10.2	1.40	5.8	10.4	9.7	0.62	6.2	10.6	9.8	0.89	5.2
15	13.3	12.3	1.68	6.9	12.5	11.7	0.74	7.4	12.7	11.8	1.07	6.3
17½	15.5	14.3	1.96	8.1	14.6	13.6	0.86	8.6	14.8	13.7	1.24	7.3
20	17.7	16.4	2.24	9.2	16.7	15.6	0.98	9.8	16.9	15.7	1.42	8.3
25	22.1	20.5	2.80	11.6	20.9	19.5	1.23	12.3	21.2	19.6	1.78	10.5
HAYS, ETC.	**ALSIKE CLOVER HAY, 1:5.5.**				**CLOVER ROWEN HAY, 1:4.9.**				**BARLEY STRAW, 1:61.0.**			
2½	2.3	2.1	0.21	1.2	2.3	2.1	0.21	1.0	2.1	2.0	0.02	1.1
5	4.5	4.1	0.42	2.3	4.6	4.2	0.43	2.1	4.3	4.0	0.04	2.1
7½	6.8	6.2	0.63	3.5	6.9	6.4	0.64	3.2	6.4	6.0	0.05	3.2
10	9.0	8.2	0.84	4.6	9.2	8.5	0.85	4.2	8.6	8.0	0.07	4.3
12½	11.3	10.3	1.05	5.8	11.5	10.6	1.07	5.2	10.7	10.0	0.09	5.3
15	13.5	12.3	1.26	6.9	13.8	12.7	1.28	6.3	12.9	12.0	0.11	6.4
17½	15.8	14.3	1.47	8.1	16.0	14.8	1.49	7.3	15.0	14.0	0.12	7.5
20	18.1	16.4	1.68	9.2	18.3	16.9	1.70	8.3	17.2	16.0	0.14	8.5
25	22.6	20.5	2.10	11.6	22.9	21.2	2.13	10.5	21.5	20.0	0.18	10.7

TABLE IV.—POUNDS OF TOTAL DRY MATTER, TOTAL ORGANIC MATTER AND DIGESTIBLE INGREDIENTS.—CONTINUED.

POUNDS OF FEED.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.
STRAWS.	OAT STRAW, 1:38.3.				WHEAT STRAW, 1:93.0.				RYE STRAW, 1:69.0.			
2½	2.3	2.1	0.03	1.2	2.3	2.1	0.01	0.9	2.3	2.2	0.02	1.0
5	4.6	4.3	0.06	2.3	4.5	4.3	0.02	1.9	4.6	4.5	0.03	2.1
7½	6.8	6.4	0.09	3.5	6.8	6.4	0.03	2.8	7.0	6.7	0.05	3.1
10	9.1	8.6	0.12	4.6	9.0	8.6	0.04	3.7	9.3	9.0	0.06	4.1
12½	11.4	10.7	0.15	5.8	11.3	10.7	0.05	4.6	11.6	11.2	0.08	5.2
15	13.9	12.9	0.18	6.9	13.5	12.9	0.06	5.6	13.9	13.4	0.09	6.2
17½	16.0	15.0	0.21	8.1	15.8	15.0	0.07	6.5	16.3	15.7	0.11	7.2
20	18.2	17.2	0.24	9.2	18.1	17.2	0.08	7.4	18.6	17.9	0.12	8.3
25	22.7	21.5	0.30	11.5	22.6	21.6	0.10	9.3	23.2	22.4	0.15	10.4
GRAINS.	CORN MEAL, 1:11.3.				CORN AND COB MEAL, 1:13.9.				OATS, 1:6.2.			
¼	0.2	0.2	0.02	0.2	0.2	0.2	0.01	0.2	0.2	0.2	0.02	0.1
½	0.4	0.4	0.03	0.4	0.4	0.4	0.02	0.3	0.4	0.4	0.05	0.3
1	0.9	0.8	0.06	0.7	0.9	0.8	0.05	0.7	0.9	0.9	0.09	0.6
2	1.7	1.7	0.13	1.4	1.7	1.7	0.10	1.3	1.8	1.7	0.18	1.1
3	2.6	2.5	0.19	2.1	2.6	2.5	0.14	2.0	2.7	2.6	0.28	1.7
4	3.4	3.3	0.25	2.9	3.4	3.3	0.19	2.7	3.6	3.4	0.37	2.3
5	4.3	4.2	0.32	3.6	4.3	4.2	0.24	3.4	4.5	4.3	0.46	2.8
7½	6.4	6.3	0.48	5.4	6.4	6.3	0.36	5.1	6.7	6.5	0.69	4.3
10	8.5	8.4	0.63	7.1	8.5	8.4	0.48	6.7	8.9	8.6	0.92	5.7
GRAINS, ETC.	PROVENDER (½ ½) 1:8.4.				PROVENDER (as sold in New England) 1:9.4.				OAT HULLS, 1:18.2.			
¼	0.2	0.2	0.02	0.2	0.2	0.2	0.02	0.2	0.2	0.2	0.01	0.1
½	0.4	0.4	0.04	0.3	0.4	0.4	0.03	0.3	0.5	0.4	0.02	0.3
1	0.9	0.9	0.08	0.6	0.9	0.9	0.07	0.6	0.9	0.9	0.03	0.5
2	1.7	1.7	0.15	1.3	1.8	1.7	0.14	1.3	1.9	1.7	0.05	0.9
3	2.6	2.6	0.23	1.9	2.7	2.6	0.20	1.9	2.8	2.6	0.08	1.4
4	3.5	3.4	0.31	2.6	3.5	3.4	0.27	2.5	3.7	3.4	0.10	1.9
5	4.4	4.3	0.39	3.2	4.4	4.3	0.34	3.2	4.6	4.3	0.13	2.4
7½	6.5	6.4	0.58	4.9	6.6	6.5	0.51	4.8	7.0	6.5	0.20	3.5
10	8.7	8.5	0.77	6.5	8.8	8.6	0.68	6.4	9.3	8.6	0.26	4.7
BYPRODUCTS.	QUAKER DAIRY FEED, 1:4.6.				H. O. DAIRY FEED, 1:3.3				VICTOR CORN AND OAT FEED, 1:10.1.			
¼	0.2	0.2	0.03	0.1	0.2	0.2	0.04	0.1	0.2	0.2	0.02	0.2
½	0.5	0.4	0.05	0.3	0.5	0.4	0.07	0.2	0.5	0.4	0.03	0.3
1	0.9	0.9	0.11	0.5	0.9	0.9	0.15	0.5	0.9	0.9	0.06	0.6
2	1.8	1.7	0.22	1.0	1.8	1.7	0.29	1.0	1.8	1.7	0.13	1.3
3	2.8	2.6	0.33	1.5	2.7	2.6	0.44	1.5	2.7	2.6	0.19	1.9
4	3.7	3.5	0.44	2.0	3.6	3.5	0.59	2.0	3.6	3.4	0.25	2.5
5	4.6	4.4	0.55	2.5	4.6	4.4	0.74	2.5	4.5	4.3	0.32	3.2
7½	6.9	6.5	0.82	3.8	6.8	6.5	1.10	3.7	6.8	6.5	0.47	4.8
10	9.2	8.7	1.09	5.0	9.1	8.7	1.47	4.9	9.0	8.6	0.63	6.4
BYPRODUCTS, ETC	H. O. HORSE FEED, 1:6.4				BARLEY, 1:8.0.				BARLEY SCREENINGS, 1:7.7.			
¼	0.2	0.2	0.02	0.1	0.2	0.2	0.02	0.2	0.2	0.2	0.02	0.2
½	0.5	0.4	0.05	0.3	0.4	0.4	0.04	0.3	0.4	0.4	0.04	0.3
1	0.9	0.9	0.09	0.6	0.9	0.9	0.09	0.7	0.9	0.8	0.09	0.7
2	1.8	1.7	0.18	1.2	1.8	1.7	0.17	1.4	1.8	1.7	0.17	1.3
3	2.7	2.6	0.28	1.8	2.7	2.6	0.26	2.1	2.6	2.5	0.26	2.0
4	3.6	3.5	0.37	2.4	3.6	3.5	0.35	2.8	3.5	3.4	0.34	2.7
5	4.5	4.4	0.46	2.9	4.5	4.4	0.44	3.5	4.4	4.2	0.43	3.3
7½	6.8	6.5	0.69	4.4	6.7	6.5	0.65	5.2	6.6	6.3	0.65	5.0
10	9.0	8.7	0.92	5.9	8.9	8.7	0.87	6.9	8.8	8.4	0.86	6.6

TABLE IV.—POUNDS OF TOTAL DRY MATTER, TOTAL ORGANIC MATTER AND DIGESTIBLE INGREDIENTS—CONTINUED.

POUNDS OF FEED.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.
BYPRODUCTS.	**WHEAT BRAN, 1:3.8.**				**WHEAT MIDDLINGS 1:4.6**				**WHEAT SCREENINGS, 1:5.2.**			
¼	0.2	0.2	0.03	0.1	0.2	0.2	0.03	0.1	0.2	0.2	0.02	0.1
½	0.4	0.4	0.06	0.2	0.4	0.4	0.05	0.3	0.4	0.4	0.05	0.2
1	0.9	0.8	0.12	0.5	0.9	0.9	0.13	0.6	0.9	0.9	0.10	0.5
2	1.8	1.6	0.24	1.0	1.8	1.7	0.25	1.2	1.8	1.7	0.20	1.0
3	2.6	2.5	0.36	1.4	2.6	2.6	0.38	1.7	2.7	2.6	0.29	1.5
4	3.5	3.3	0.48	1.8	3.5	3.4	0.50	2.3	3.5	3.4	0.39	2.0
5	4.4	4.1	0.60	2.3	4.4	4.3	0.63	2.9	4.4	4.3	0.49	2.5
7½	6.6	6.2	0.90	3.4	6.6	6.4	0.94	4.4	6.6	6.5	0.74	3.8
10	8.8	8.2	1.20	4.6	8.8	8.5	1.25	5.8	8.8	8.6	0.98	5.1
BYPRODUCTS, ETC.	**MIXED (wheat) FEED, 1:3.9.**				**RED-DOG FLOUR, 1:3.3.**				**RYE, 1:7.8.**			
¼	0.2	0.2	0.03	0.1	0.2	0.2	0.04	0.1	0.2	0.2	0.02	0.2
½	0.4	0.4	0.07	0.3	0.5	0.4	0.09	0.3	0.4	0.4	0.04	0.3
1	0.9	0.8	0.13	0.5	0.9	0.9	0.18	0.6	0.9	0.9	0.09	0.7
2	1.8	1.7	0.27	1.0	1.8	1.7	0.36	1.2	1.8	1.7	0.18	1.4
3	2.7	2.5	0.40	1.5	2.7	2.6	0.53	1.7	2.7	2.6	0.27	2.1
4	3.6	3.3	0.53	2.1	3.6	3.6	0.71	2.3	3.5	3.5	0.36	2.8
5	4.5	4.3	0.67	2.6	4.6	4.4	0.89	2.9	4.4	4.4	0.46	3.5
7½	6.7	6.3	1.00	3.8	6.8	6.5	1.34	4.4	6.6	6.5	0.67	5.2
10	8.9	8.4	1.33	5.2	9.1	8.7	1.78	5.8	8.8	8.7	0.89	6.9
BYPRODUCTS.	**RYE BRAN, 1:5.1.**				**COTTONSEED MEAL, 1:1.0**				**COTTONSEED FEED, 1:5.6**			
¼	0.2	0.2	0.03	0.2	0.2	0.2	0.10	0.1	0.2	0.2	0.02	0.1
½	0.4	0.4	0.06	0.3	0.5	0.4	0.20	0.2	0.4	0.4	0.04	0.2
1	0.9	0.9	0.12	0.6	0.9	0.9	0.40	0.4	0.9	0.9	0.08	0.4
2	1.8	1.7	0.25	1.3	1.8	1.7	0.80	0.8	1.8	1.1	6.16	0.9
3	2.7	2.6	0.37	1.9	2.8	2.6	1.20	1.2	2.1	2.6	0.24	1.3
4	3.5	3.4	0.49	2.5	3.7	3.4	1.60	1.6	3.5	3.4	0.32	1.8
5	4.4	4.3	0.62	3.1	4.6	4.3	2.00	2.0	4.4	4.3	0.40	2.2
7½	6.6	6.4	0.92	4.7	6.9	6.4	3.00	3.0	6.6	6.4	0.59	3.3
10	8.8	8.5	1.23	6.3	9.2	8.5	4.00	4.0	8.8	8.5	0.79	4.4
BYPRODUCTS.	**COTTONSEED HULLS, —**				**LINSEED MEAL (O.P.) 1:1.5**				**LINSEED MEAL (N. P.), 1:1.3**			
¼	0.2	0.2	....	0.1	0.2	0.2	0.08	0.1	0.2	0.2	0.08	0.1
½	0.4	0.4	....	0.2	0.5	0.4	0.15	0.2	0.4	0.4	0.16	0.2
1	0.9	0.9	....	0.4	0.9	0.8	0.31	0.5	0.9	0.8	0.32	0.4
2	1.8	1.7	......	0.7	1.8	1.7	0.63	1.0	1.8	1.7	0.65	0.8
3	2.7	2.6	....	1.1	2.7	2.5	0.92	1.4	2.7	2.5	0.97	1.3
4	3.6	3.4	....	1.5	3.6	3.4	1.23	1.8	3.6	3.4	1.30	1.7
5	4.5	4.3	..	1.8	4.9	4.2	1.54	2.3	4.5	4.2	1.62	2.1
7½	6.7	6.5	....	2.7	6.8	6.3	2.31	3.4	6.7	6.3	2.43	3.2
10	8.9	8.6	....	3.7	9.0	8.4	3.08	4.6	8.9	8.4	3.24	4.2
BYPRODUCTS.	**FLAX MEAL, 1:1.4.**				**GLUTEN MEAL (Chicago) 1:1.5.**				**GLUTEN MEAL (Cream) 1:1.7.**			
¼	0.2	0.2	0.08	0.1	0.2	0.2	0.08	0.1	0.2	0.2	0.07	0.1
½	0.4	0.4	0.16	0.2	0.4	0.4	0.16	0.2	0.4	0.4	0.15	0.2
1	0.9	0.8	0.32	0.4	0.9	0.9	0.32	0.5	0.9	0.9	0.30	0.5
2	1.8	1.7	0.64	0.9	1.8	1.7	0.64	0.9	1.8	1.8	0.59	1.0
3	2.7	2.5	0.96	1.3	2.6	2.6	0.96	1.4	2.7	2.7	0.89	1.5
4	3.6	3.4	1.28	1.7	3.5	3.4	1.28	1.9	3.6	3.6	1.19	2.1
5	4.5	4.2	1.60	2.2	4.4	4.3	1.60	2.3	4.5	4.5	1.49	2.6
7½	6.7	6.3	2.40	3.3	6.6	6.5	2.40	3.5	6.7	6.7	2.23	3.9
10	8.9	8.4	3.21	4.3	8.8	8.6	3.21	4.7	9.0	8.9	2.97	5.1

TABLE IV.—POUNDS OF TOTAL DRY MATTER, TOTAL ORGANIC MATTER AND DIGESTIBLE INGREDIENTS—CONTINUED.

POUNDS OF FEED.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.	Total dry matter.	Organic matter.	Protein.	Carbohydrates, etc.
BYPRODUCTS.	GLUTEN MEAL (King), 1:1.9.				GLUTEN FEED (Buffalo or Marshalltown) 1:2 4				GLUTEN FEED (Diamond or Rockford), 1:3 0.			
¼	0.2	0 2	0.07	0.1	0.2	0.2	0.06	0 1	0.2	0.2	0 05	0.2
½	0.5	0 5	0.15	0 3	0.4	0.4	0 12	0 3	0.5	0 4	0 10	0.3
1	0.9	0 9	0 30	0.6	0.9	0 9	0 23	0.6	0 9	0.9	0 20	0.6
2	1.9	1 7	0.59	1 1	1.8	1.8	0 47	1 1	1.8	1.8	0.41	1 2
3	2 8	1.8	0.89	1.7	2 7	2.6	0.70	1.7	2.7	2 7	0.61	1.9
4	3.7	3 7	1 19	2 3	3 6	3.5	0.93	2 3	3.6	3.6	0.81	2.5
5	4.6	4.6	1.49	2 8	4 5	4 4	1 17	2.8	4.6	4.5	1 02	3.1
7½	6 9	6.9	2.23	4.3	6.8	6 6	1.75	4.2	6 8	6 8	1 52	4.7
10	9.3	9.2	2 97	5 7	9.0	8.8	2 33	5 7	9.1	9 0	2.03	6.2
BYPRODUCTS.	HOMINY CHOP, 1:9.2.				STARCH FEED, WET, 1:4 9				DRIED BREWERS GRAINS, 1:3.0.			
¼	0.2	0.2	0.02	0 2	0.1	0.1	0 01	0 1	0.2	0 2	0 04	0.1
½	0.5	0.4	0.04	0.4	0 2	0.2	0.03	0 2	0 5	0 4	0.08	0.2
1	0.9	0.9	0.09	0.8	0 3	0.3	0.05	0.3	0 9	0.9	0 16	0 5
2	1.8	1.8	0.17	1.6	0.7	0 6	0.11	0 5	1.8	1.8	0.31	0.9
3	2 8	2.7	0 26	2.4	1.0	1 0	0.16	0.8	2.8	2.6	0.47	1.4
4	3.7	3.6	0.35	3.2	1.4	1.4	0.22	1.1	3.7	3.5	0 63	1.9
5	4.6	4 5	0.44	4.0	1.7	1 7	0.27	1.3	4 6	4 4	0 79	2.4
7½	6.9	6 7	0.65	6.0	2 6	2 6	0.41	1.7	6 9	6.6	1.18	3.5
10	9.2	8.9	0 87	8.0	3.5	3.4	0 54	2.6	9 2	8 8	1 57	4.7
BYPRODUCTS	ATLAS GLUTEN MEAL, 1:2 6.				MALT SPROUTS, 1:2.2.				PEA MEAL, 1:3 2			
¼	0 2	0.2	0.06	0.2	0.2	0.2	0.05	0.1	0.2	0.2	0.04	0.1
½	0.5	0 4	0 12	0 3	0.4	0.4	0.09	0.2	0 4	0 4	0 08	0.3
1	0.9	0 9	0.25	0.6	0 9	0.8	0 19	0.4	0 9	0.9	0 17	0.5
2	1.8	1.8	0 49	1.3	1.8	1.7	0.37	0 8	1 8	1 7	0.33	1.1
3	2.8	2.7	0.74	1 9	2.7	2 5	0.56	1 2	2.7	2.6	0.50	1.6
4	3 7	3.6	0.98	2 6	3.6	3.3	0 74	1.6	3.6	3 5	0.67	2.1
5	4.6	4 5	1.23	3.2	4.5	4.2	0.93	2 0	4 5	4 4	0.84	2.7
7½	6.9	6.7	1 85	4 9	6.7	6 3	1 40	3.0	6.7	6.5	1.26	4.0
10	9.2	9 0	2 46	6 5	9 0	8.4	1.86	4.0	9.0	8.7	1.68	5.3

After the table of feeding standards has been selected, and the table of chemical composition with those of the digestible substances present in the feeding materials, the problem remains for the farmer to apply and test them thoroughly in order that they may be useful.

Table IV, a convenience table, with Nos. II and III, have been taken from bulletin 81 of the Vermont experiment station by Prof. J. L. Hills. The convenience table will save much of the tedious work connected with the calculation of a ration. In order to illustrate the use of the tables and the feeding standards, it would be well to let Professor Hills explain the use of the convenience table in his article on this subject.

CALCULATION OF A FEEDING RATION.

"Let it be assumed, for the illustration, that a farmer has a cow weighing about 900 pounds and giving about 30 pounds of milk a day, to which he wishes to feed a ration balanced according to the Wolff-Lehmann standard; that he has hay (timothy, Kentucky bluegrass, clover, etc., essentially 'mixed grasses'), fairly mature corn silage, bran and cob meal, and that he can buy cottonseed meal, Chicago gluten meal, Quaker dairy feed, mixed (wheat) feed, Buffalo gluten feed and hominy chops. How shall he proceed to figure out his ration? Reference to the standard shows that the 1,000-pound cow shou'd be fed 32 pounds of dry matter, 3.3 pounds protein, 13 pounds carbohydrates and 0.8 pounds ether extract, nutritive ratio, 1:4.5. The ether extract figures are multiplied by 2.25* and added to those of the carbohydrates, and then all the figures are multiplied by nine-tenths. This latter is done because a 900-pound cow weighs nine-tenths what a 1,000-pound cow does, and is held, according to the standard, to need approximately but nine-tenths the nutrition. As a matter of fact, she probably needs a little more than this.

"$0.8 \times 2.25 = 1.8$. $13 + 1.8 = 14.8$. $32.0 \times .9 = 28.8$. $3.3 \times .9 = 2.97$. $14.8 \times .9 = 13.3$.

"The Wolff-Lehmann standard for a 900-pound cow giving 30 pounds milk, therefore, requires that the daily food shall contain 28.8 pounds total dry matter, 2.97 pounds digestible protein, 13.3 pounds digestible carbohydrates and ether extract; and, if this is fed, the nutritive ratio will be 1:4.5.

"The next step is to supply these nutrients. The convenience table (table IV) shows that of the feeds on hand bran alone has a nutritive ratio (1:3.8) narrower than the standard. The hay, silage and cob meal have 'wide' ratios (1:10.0, 1:14.8, 1:13 9), all wider than the standard. Hence purchases must be made, and these must be of goods with narrow ratios. The materials available are found to have ratios as follows from narrowest to widest: Cottonseed meal, 1:1.0; Chicago gluten meal, 1:1.5; Buffalo gluten feed, 1:2.4; mixed (wheat) feed, 1:3.9; Quaker dairy feed, 1:4 6, and hominy chop, 1:9.2. It is at once perfectly clear that the latter two feeds will not aid in balancing the ration, and that the mixed (wheat) feed will not be of much avail. Hence choice should be made of one or

*To reduce the ether extract to the same food value and—assumedly—feeding value as the carbohydrates.

more of the first three, according to price and other considerations. Let us assume that the cottonseed and Buffalo goods be chosen and proceed to figure our ration.

"It is generally desirable to make as large use of roughages as possible because of their cheapness. The amounts which can be consumed vary with different animals. In dairy feeding, however, more than half, and often as much as two-thirds, of the total dry matter should be given in the form of roughage.

"Let us, as a preliminary trial, take 10 pounds hay, 25 pounds silage, 4 pounds bran and 1 pound each of cottonseed meal and Buffalo gluten feed. Turning to the 'convenience table,' we find the total dry matter, digestible protein and carbohydrates, etc., calculated for these weights:

	Dry matter.	Digestible protein.	Digestible carbohydrates.	Nutritive ratio.
Hay, 10 pounds	8.5	0.44	4.4	
Silage, 25 pounds	6.6	0.30	4.5	
Bran, 4 pounds	3.5	0.48	1.8	
Cottonseed meal, 1 pound	0.9	0.40	0.4	
Buffalo gluten feed, 1 pound	0.9	0.23	0.6	
Total	20.4	1.85	11.7	1:6.3
Standard	28.8	2.97	13.3	1:4.5

"How do they compare? Eight pounds short in total dry matter, one pound short in protein, one and one-half pounds short in carbohydrates; 30 per cent lacking in dry matter, nearly 40 per cent in protein, but only 12 per cent short in carbohydrates. What shall be used to bring the ration up? More roughage will increase carbohydrates faster than protein; more bran will do the same, but not as rapidly; more cottonseed meal will not, and more gluten food will help more than it will hinder. Inasmuch as it is of doubtful wisdom to feed cottonseed meal very heavily, let us see what the addition of 2 pounds of cottonseed meal and 1 pound of gluten feed will do.

	Dry matter.	Digestible protein.	Digestible carbohydrates.	Nutritive ratio.
Cottonseed meal, 2 pounds	1.8	0.80	0.8	
Buffalo gluten feed, 1 pound	0.9	0.23	0.6	
Total	2.7	1.03	1.4	
Former result	20.4	1.85	11.7	
New total	23.1	2.88	12.8	1:4.4
Standard	28.8	2.97	13.3	1:4.5

"The ration now 'balances,' yet is still nearly 6 pounds short of total dry matter. Since the ration is a shade narrow

rather than wide, one will naturally add now the material with the widest ratio, *i. e.*, silage. But there is a limit to the bulk the animal can handle, so that hay may be preferable with some animals. Let us increase the hay 2½ pounds.

	Dry matter.	Digestible protein.	Digestible carbohydrates.	Nutritive ratio.
Hay, 2½ pounds	2.1	0.11	1.1	
Second total	23.1	2.88	12.8	
New total	25.2	2.99	13.9	1:4 6
Standard	28.8	2.97	13.3	1:4.5

"The result is still low in total dry matter, while giving plenty of nutrients. The ration lacks slightly in bulk but not in food. To try and obtain bulk with fodders on hand would result in feeding more than the standard amounts of the nutrients. Bulk without much nutriment could be furnished by straw, but, as a matter of fact, this is not very important. A ration of 12.5 pounds hay, 25 pounds silage, 4 pounds bran, 3 pounds cottonseed meal and 2 pounds of Buffalo gluten meal would meet the Wolff-Lehmann standard requirements for a 900 pound cow with a sufficient approximation to accuracy.

"This is a very narrow ration, and, if ever adopted, should be used with caution particularly at the outset. Three pounds of cottonseed meal is heavy feeding, heavier than is often advisable. Were half this replaced with linseed the ration would be the safer but a trifle poorer in protein.

"The longer and complete figuring is carried out as follows: The average analysis of mixed hay, so far as it pertains to the ingredients called for in the determination of the standard, is as follows (Table II): Dry matter 84.7 per cent (100—15.3 per cent water), crude protein 7.4 per cent, crude fiber 27.2 per cent, nitrogen-free extract 42.1 per cent, ether extract 2.5 per cent The digestion coefficients for these ingredients are respectively (Table III), .59, .60, .59, and .49. Multiplying each percentage by its digestion coefficients gives the digestible ingredients in 100 pounds (Table III), protein, 4.4 (7.4×.59) crude fiber, 16.3 (27.2×.60), nitrogen-free extract, 24.8 (42.1×.59) ether extract, 1.2 (2.5×.49). Adding the fiber and the nitrogen-free extract and 2.25 times the ether extract for "carbohydrates and ether extract," we get 43.9. Ten pounds of hay being fed, each figure is multiplied by .10 (10 being 1-10 of 100) with results as follows: In 10 pounds of mixed hay, total dry matter 8.5 pounds, protein 0.44 pounds, carbohydrates etc., 4.4 pounds. These are the figures given on the top line of the table on page

484, which were read directly from the convenience table (Table IV), at the left hand side of page 479. The use of this table obviates this tedious though simple calculation "

For a consideration of the subject in general, Professor Henry's work on "Feeds and Feeding" is recommended for those who may desire to study the subject more thoroughly than it is possible to present in this paper.

CONDIMENTAL FOODS.

At present in addition to the important question relating to feeds and feeding the farmer has his attention attracted to the various advertisements of the so-called "cattle-foods" and the extraordinary claims made for these substances often lead one to conclude that it would be wise to give them a trial The following extract is taken from Bulletin No. 166 of the New York Experiment Station and presents the results of an investigation which will be of value to those interested in this subject.

"There is found very prevalent in our markets a class of substances bearing the term "food" that are noted chiefly for being sold in small packages at remarkable prices, on the strength of claims which are sometimes startling even in this time of daily miracles as set forth in the advertising columns of our newspapers. These proprietary wonders are usually marvelous both in their nutritive and their healing effects, for if one may believe the statements concerning some of them, they are remarkably loaded with nutritive energy and the diseases they will not cure would be highly interesting to the veterinarian as pathological novelties. It is most surprising to find after being told that the effect of these "foods" is to enrich milk, produce bovine obesity with remarkable rapidity and banish disease, that so far no one of them has been examined that is not made up largely of some common grain product mixed with more or less of the commonest drugs and other substances having little curative value, nearly all of which of any merit whatever may be found on the pantry shelf or in the horse stable of many farms. It is strange, too, that farmers have not long ago discovered for themselves, if it is true, that when bran or some other common feeding stuff is compounded with the equally common charcoal, salt, sulphur, saltpetre, fenugreek, etc., the nutritive power of the food is greatly enhanced and the drug takes on unheard of curative properties. Nevertheless we are asked to believe such is the case. No

evidence of the accuracy of these unusual properties is furnished, save the usual list of testimonials, the reliability of which may be judged in the light of the fact that some of the most absurd impositions ever perpetrated on the public have been abundantly approved by similar evidence. Years ago Lawes & Gilbert condemned patent foods at the prices for which they are sold, and important experiments conducted in recent years have not furnished the least justification of their purchase by stockmen. Farmers may accept with perfect confidence this statement, viz.: That there are no nutritive properties, compounds or influences yet discovered which are not possessed by the common feeding stuffs, neither is it possible to increase for well animals the nutritive effects of protein and carbohydrates by associating with them any compounds or drugs whatever.

As to the medicinal value of condimental foods, it may be safely asserted that well animals, properly fed, need no medicine, and sick animals should receive treatment specifically adapted to their ailments. Universal preventatives and cure-alls of diseases are unknown and believed in only by those who are ignorantly credulous. More than this, many of the constituents of condimental foods have no recognized curative value.

But notwithstanding all that has been said again and again to the farming public concerning condimental foods, they still find a sale. Not less than fifteen brands have been examined at this station during the past two years, all of which were found in New York markets. Their analyses from a food standpoint follow:

SAMPLES OF PATENT FOODS COLLECTED IN NEW YORK DURING 1898 AND 1899.

Station No.	Sample; where collected.	Price per pound.
445	Corning	
446	Corning	$ .20
448	Hornelsville	.05
450	Hornelsville	.25
451	Hornelsville	.07½
456	Canisteo	.25
457	Dansville	.18
458	Dansville	.10½
459	Dansville	.13½
460	Mt. Morris	.06½
461	Mt. Morris	.10
462	Buffalo	.50
502		.15

ANALYSES OF SAMPLES OF PATENT FOOD.

Station No.	NAME.	Water, per cent.	Ash, per cent.	Crude protein, per cent.	Crude fiber per cent.	Starch and Sugar per cent.	Ether extract, per cent.
445	Flower City Horse and Cattle Food	9.27	11.29	14 37	9.70	21.0	5.12
446	International Stock Food	8.13	9.92	13.88	5.68	21 9	7.91
448	Blatchford's Calf Meal	7.12	5.74	26 13	4.23	22.7	4 56
450	Nutritone	6 90	20.17	22.19	4.94	23.5	5.13
451	Pratt's Cattle Food	7.25	6.36	14 56	5.78	35.4	7.53
456	Rochester Horse and Cattle Food	8.00	8.19	18.44	10.59	21.5	3.61
457	Anglo-American Food for Stock	7.20	13.28	15.50	7.86	25 8	4.85
458	Climax Food	7.24	21 09	9 94	4.14	17.2	*22 53
459	Colonial Stock Food	7.28	14.51	9.81	11 99	28 8	2.54
460	Royal Stock Food	5.56	44.07	11.25	9 73	13 7	3.52
461	Baums' Horse and Stock Food	8.05	10 87	27.81	13.00	9.2	7.75
462	Chas. Marvin Stock Food	8 26	5 97	30.94	10 63	18.2	4 28
485	Triplex Stock Food	7.10	12.05	15.31	6 31	28.8	5.66
502	Champion Horse and Cattle Food	8.99	14.40	10 69	4.74	41.2	4.68
539	Wilbur's Seed Meal	7.13	12.16	20 00	8.18	20.9	5 63

"In these mixtures were found as the principal constituent some common feeding stuff like bran or other wheat offals, corn offals, linseed meal and so on. The special ingredients, added ostensibly for medical effect, were found to include charcoal, fenugreek, gentian, sulphur, salt, saltpetre, sodium sulphate, iron compounds and pepper.

"Particular attention is called to the prices at which these 'foods' are sold. The range is from $100 to $500 per ton, which is at least from $70 to $470 per ton more than the materials are worth for food purposes. It may be claimed, as some of the manufacturers urge, that these mixtures should be regarded as medicines. Even if this is true, the farmer who wishes to administer any of these common substances to his animals can do so at a small fraction of their cost in condimental feed by purchasing them as drugs and then mixing them with the grain ration as he wishes. For the promoters of these mixtures to claim that they have any knowledge of compounds and compounding not common to veterinary medicine is charlatanism in its most offensive form.

"Blatchford's calf meal is advertised as a food of great value. Director Woods, of the Maine station, has given this

*Mostly Sulphur.

product a careful examination, and his report concerning it includes the following statements:

"'These goods were sent to an expert on food mixtures and adulterations, at the Connecticut experiment station, who reports as follows: "I have examined Blatchfords calf meal under the microscope, and find it contains linseed meal, some product from the wheat kernel, some product from the bean kernel and a little fenugreek. The linseed meal appears to be the chief constituent. The wheat product is bran, middlings or some similar product consisting of starchy matter mixed with more or less of the seed coats. Bean bran was present in considerable amount and more or less of the starchy matter."

"'In a letter just at hand from Mr. J. Barwell, the proprietor of these goods, he says: "Regarding the ingredients, I cannot give you the exact constituents of it, but I may say that it is composed mostly of locust bean meal with leguminous seeds, such as lentils, etc., and oleaginous seeds, such as flax seed, fenugreek and anise seed, all cleaned, hulled and ground together and thoroughly well cooked. There is no cheap mill food and no low grade feed enters into its composition. I am prepared to go into any court in the United States and make an affidavit that there is no farmer in the United States that can compound Blatchford's calf meal for less than $3.50 per hundred."

"'Locust bean meal, which Mr. Barwell claims to be the chief constituent of Blatchford's calf meal, is practically not used in this country as a cattle feed. The average of ten English and German analyses show it to carry: Water, 14.96 per cent; ash, 2.53 per cent; protein, 5.86 per cent; crude fiber, 6.39 per cent; nitrogen free extract, 68.98 per cent; fat, 1.28 per cent.

"'It is evident, from the chemical analyses, that locust bean meal cannot be the chief constituent of Blatchford's calf meal, but that the microscopist is correct that linseed meal is the chief constituent. Locust bean meal has only 6 per cent of protein, and, in order to make a mixture carrying from 26 to 33 per cent of protein, it would be necessary to add large quantities of goods, like linseed meal, rich in protein. As seen from the analyses, Blatchford's calf meal has a feeding value somewhat inferior to old process linseed meal. Whatever it may cost to manufacture, no man who has sufficient intelli-

gence to mix feeds can afford to buy it at anything like the price asked.'

"In the light of this information the farmers of New York must decide whether they can afford to pay at the rate of $100 per ton for materials no more valuable than those which are generally offered in our markets at ordinary prices. Special mention is made of this feed because it is sold for distinctively food purposes, and because, prices considered, it perhaps does the farmer's pocketbook as little harm as any other food mentioned in the above list, and less than all excepting No. 462. At the same time it typifies all those efforts here discussed of mixing common materials and selling them under extraordinary names at extraordinary prices."

LAWNS AND LAWN MAKING IN IOWA.

A discussion of the subject of grasses would be incomplete without some reference to lawns. There are few subjects of more general interest to the business man and owner of a home than the preparing and maintaining of a lawn. Nothing adds so much to the beauty of a home as a well-kept lawn. The owner of a few feet of ground delights in the smooth even turf as much as the owner of acres of ground Nor does anything add so much to the beauty of the home as a green well-kept lawn, whether this consists of a few feet or a broad and large lawn with acres of ground, with its broad vistas and beautiful shrubbery here and there. A good, well-kept lawn should not only please the eye but be restful to those who make use of it.

How to obtain a good lawn is not understood by everyone. Lamson-Scribner says:* "Firmness and permanency may be secured, but they are results which cannot be obtained by hasty and unskilled preparation. A perfect lawn cannot be made in a season, and the highest excellence sought comes only through intelligent care for a period of years. A green surface may be secured within a few months under favorable conditions, but a soft, velvety turf, which is both a delight to view and to walk on, comes only with years of patient care."

"In regard to the preparation and general treatment the published paper of Lamson Scribner may be used in this connection.

Preparation of the Land.—"In what follows, proper grading and thorough drainage are presupposed. A well-drained soil is of the first importance and is absolutely necessary to success. Where the process of grading has involved much filling in; time should be allowed for the settling of the soil, and during this period a hoed crop may be cultivated on the land to advantage. If the land is very weedy, the cultivation of corn or potatoes for a season will assist in reducing the stock of weeds. It must be remembered that the lawn when once

*Yearbook U. S. Dept. Agrl. 1897: 355-378.

formed is to remain undisturbed; the sward is to be permanent, and hence the importance of most thorough preparation of the soil. In most cases, particularly in eastern and northern states, a liberal application of fertilizers is necessary. If the land is native sod, this should be top-dressed in the fall with well-rotted stable or barnyard manure, and the sod then turned by plowing. The decomposition of this sod will add to the soil that most valuable of fertilizing elements, humus. In the following spring a top-dressing of old well-composted manure should be applied at the rate of 8 to 12 cords to the acre, according to the natural fertility of the soil, and the land cross plowed. The surface then should be made as fine as possible by repeated harrowings and thorough rolling before the seed is sown. The deeper the soil is stirred in plowing the better the results and the less care will be required in keeping the soil in good condition.

"The nature of the subsoil has great influence upon the growth of the grass and the permanence and beauty of the lawn. Over a light and gravely subsoil the grass is not infrequently destroyed by summer drought. The best soil for the formation of the lawn is a fine, sandy loam over clay subsoil. Where the effects of heat and drought are most severely felt, the soil must be most deeply and thoroughly worked in its preparation. It not infrequently happens in the case of dooryards and plots surrounding city and suburban residences that the soil is largely composed of the earth excavated in making the foundations. This earth is entirely unsuited for the growth of grass, and, where a lawn is desired, should be entirely removed or covered to a sufficient depth with fine earth rich in humus, to insure the healthy and permanent growth of the grass. This added soil should be at least one foot in depth and a depth of two feet will repay the extra labor in the final results.

"In western states and in the south it is not customary to stir the soil so deeply as recommended above. The practice, however, can well be applied in most localities in the south, but in the west, where the soil conditions are essentially different from those in the east, the method pursued must be governed by the local requirements. A coarse, uneven soil will only yield coarse grasses and finely worked surface will produce the finer sorts, which alone are desired.

Fertilizers.—"Reference has already been made to the use of well-rotted barnyard or stable manure in the preparation of the land for lawns. This is the best fertilizer to apply when it is to be plowed under, but only old and well-composted manure should be used. When such cannot be obtained, commercial fertilizers may be substituted, and with these a liberal supply of lime and bone meal can be worked into the soil before seeding. Where it is necessary to apply fertilizers after the grass has started in order to maintain fertility, land-plaster, bone meal, nitrate of soda and hard wood ashes are most commonly employed. A full dressing of clear sheep manure, three to five tons per acre, followed by an early spring dressing of unbleached hard wood ashes (containing 8 per cent potash) at the rate of three to five tons per acre, according to the fertility of the soil, is advised by one correspondent.

"A common practice is to top dress lawns in the fall or early winter with a compost, adding in the spring a dressing of bone meal and hard wood ashes; in the place of the fall dressing of compost, hard wood ashes may be substituted A too frequent use of hard wood ashes, however, is to be avoided, as it will induce the growth of clover at the expense of the grasses. Bone meal, hard wood ashes and lime are the fertilizers most generally used to maintain the fertility of the lawn, whether shaded or exposed to the sun. When the soil has been properly prepared and enriched, there is little difficulty in securing a good growth of grass under the trees if the branches are not too low.

Selection of Lawn Grasses.—"The value and beauty of a lawn depends upon the color, texture and turf-forming habit of the grass selected. A grass may be of good color but harsh in texture and incapable of producing a turf, or it may form a good sward and have a satisfactory texture, but be deficient or even unsightly in color."

Kind of Lawn Grass for Iowa—The value and beauty of a lawn grass depends upon the texture and color of the grass, one that forms a good turf. In Iowa we have but one species that is generally used, namely, blue grass. In the tropical countries turf-forming grasses are almost unknown, so in the warmer parts of our own country the good turf-forming grasses are less common than in Iowa. The chief glory of our northern landscapes are the fine turf-forming grasses, and in the Mississippi valley blue grass is preëminent. "Turf grasses

are the pasture grasses of New England and the middle states. Nowhere will we find a better turf or a finer or more even texture or more pleasant to walk on, than in some of the pastures near the New England coast, which have been grazed by sheep for the past hundred years or more. Where these pastures have been grazed the closest and trampled the most, there will be the closest and most even turf, composed generally of a single variety of grass. Such turf as we are considering (turf suitable for lawns) is produced either by the grazing of stock, particularly sheep, or by the frequent and intelligent use of the lawn mower and roller. The value of sheep in turf formation is recognized by the managers of public parks, and has been taken advantage of by some This is notably the case in Central Park, New York, and Druid Hill Park, Baltimore." In the semi-arid regions of the west the smooth, even turfs are wanting, the species frequently growing in bunches. Northwestern Iowa departs somewhat from the conditions prevailing in other sections of the state, since the rainfall for a good turf is somewhat deficient.

In regard to the color and texture: "A deep, rich emerald green is the shade most desired in a lawn grass, as it is generally pleasing and certainly the most beautiful of all tints. No grass in the northern and middle states fills this requirement so well as Kentucky blue grass; the color of this grass, when grown under favorable conditions, may be regarded as the standard upon which to base comparisons. Different varieties of Kentucky blue grass show slight variations in color, some being lighter than others, but upon the whole the deep, rich shade of green may be relied upon. Some of the fescues possess an equally deep shade of green, but the best turf-forming varieties of this grass usually have a grayish tint, which is more or less objectionable. Creeping bent and Rhode Island bent are very much alike in color, but they are considerably lighter than the Kentucky blue grass; and, should this be regarded as a fault, it is fully counterbalanced by their finer texture and superior turf-forming habit. Italian rye grass has a good color, and the fine-leafed variety of perennial rye grass is by no means an inferior lawn grass. The color of these rye grasses is not very different from Kentucky blue grass, but there is a marked difference in the appearance of the herbage; the surface of the leaves of perennial rye grass

has a shining or polished appearance not apparent in Kentucky blue grass."

"Reference has already been made to the degree of fineness of several varieties of grasses, but the narrowness of the leaf blade does not always determine the texture. Some of the varieties of fescuses have exceedingly narrow or thread-like leaves, but the turf formed by them may be harsh and unpleasant to the touch. Other grasses again may have comparatively broad leaves, which are soft and flexible, and the turf they produce may possess a desirable texture."

Varieties.—The Iowa lawn is generally represented by but a single species of grass, namely, blue grass (*Poa pratensis*). White or Dutch clover (*Trifolium repens*) is frequently sown and when not sown frequently comes into the lawns and is most desirable. The fescue grasses and timothy are sometimes sown, more frequently to obtain a quick growth of grass, but neither has an abiding place. The bent grasses (*Agrostis alba*) are sometimes found, but in old lawns it seldom finds a place; the blue grass crowds all but the clover out. The best lawns are those that consist of but a single species

Selection of Seed.—"The greatest care should be taken to procure seeds of the very best quality of the variety desired. The highest priced seed is the cheapest in the end. A cheap grade may always be looked upon with suspicion, and is usually dear at any price, and the sowing of seed of any grade upon a poorly prepared seed bed is wasteful.

"It has long been a common practice to use a variety of seeds or so-called "lawn mixtures" in seeding down lawns. Those advocating these mixtures argue that there is no one grass that will suit the ordinary lawn maker, as he wants a lawn quickly, he wants a lawn fine, and he wants it to be permanent, results which it is claimed can only be obtained by mixtures. Further, it is asserted that the variety in the mixture best suited to the soil and climatic conditions will eventually run out the others, and the lawn will finally be composed of a single species. This course will manifestly cause a delay in securing a satisfactory turf, and when there are several varieties of grasses combined the liability of introducing weed seed is greatly increased.

"One of the chief features of beauty in a lawn, as already stated, is uniformity in color, and this cannot be obtained by a mixture of varieties of grasses; the color will always be mottled

and irregular. Under the most favorable conditions it is difficult to procure absolute uniformity in color, for there is likely to be a variation in the shade of tint between individuals of the same species.

"Uniformity of texture is impossible where two or more varieties of grasses are sown; no two species possess exactly the same degree of finness, and even individual plants or strains of the same species are apt to vary in this particular.

"The mixing of creeping bent with Kentucky blue grass is like mixing the good with the bad, and such a combination has a real disadvantage, which is particularly manifest in the later autumn months when the distinctive coloring of the two grasses is especially pronounced. The lawn composed of these two species is then almost unsightly because of its decided mottled appearance; the dark green of the blue grass stands out in striking contrast with the paler color of the creeping bent. For the same reason white clover should never be sown with the bent grasses.

The Amount of Seed Used per Acre.—"The amount of seed to be used will depend somewhat on the character of the soil, but more particularly upon the quality and kind of seed used. The seed, of course, should be sown much more thickly than for hay production, and allowance has to be made for the thoroughness with which the seed has been cleaned from chaff. Rhode Island bent and creeping bent are both likely to contain a large amount of chaff and imperfect seeds, and the quality of seed sown should be sufficient to make allowance for this. Under the new methods of cleaning seeds of Kentucky blue grass, the chaff is almost entirely removed, but in the case of this grass there is often a lack of vitality, or germinating power, and it is always best to use a liberal quantity in seeding down a lawn.

"Mr. William Doogue, superintendent of public grounds, Boston, sows four bushels of Kentucky blue grass and red top, mixed in equal parts, to which about six pounds of white clover have been added, to the acre, or one peck to 300 square yards. Owing to the great variation in the weight per bushel of grass seeds of the same kind (due to the presence of more or less chaff), it is best to base the amount upon weight rather than measure, and from fifty to sixty pounds of seed of fine quality is not too much to use upon an acre of ground, or one and one-half pounds to 100 square yards. Poor land requires

more seeding than fertile land. Some advise as much as 100 pounds of seed to the acre."

Time of Seeding.—In this state it is advisable to sow as early as possible in the spring—middle of March to first of April. Fall is uncertain with dry weather. In September it is difficult to get a stand, although, if the fall is a favorable one for rains, September is a good month to sow. This will enable the roots to get a good start to prevent winter killing, which takes place frequently when the young plants are thrown out of the ground and drying out. A better start with blue grass may be obtained by sowing a small amount of white clover. "The seed must be sown or scattered evenly over the surface if a patchy and unsightly growth is to be avoided. It is best to select a time when there is little or no wind and, if possible, immediately previous to an expected rain. Care must be taken not to cover the seed too deeply. A very light raking or brushing may be allowed and is even advantageous, but generally rolling will be sufficient. The rolling is necessary to make the surface soil firm, to press the seeds into close contact with the earth and to render the surface smooth and even. The germination of the seed largely depends upon the depth to which it is covered. An eighth of an inch is ample covering for most grass seeds, while Kentucky blue grass is said to germinate best when exposed to the light and consequently not covered at all."

Transplanting Turf.—In the town lot or some public places the transplanting of turf is often resorted to. The first desideratum is a pure turf of one variety of grass, and this is not difficult to obtain anywhere in Iowa. The turf is cut to appropriate lengths. The ground which is to receive the turf should be well loosened; the turf is laid closely, rolled and watered. In this way a fine turf may be had the first season. "Where the supply of pure turf is limited, but still can be obtained, it may be cut into small pieces two or three inches square and these set out at intervals of six or eight inches, being pressed into the soil about one-half inch below the uncovered surface, which will eventually settle a little, and, if the soil has been properly prepared, the growth of the grass will soon cover the ground and make a satisfactory sward much more quickly than can be obtained by seeding. This method has the advantage, too, of insuring the production of exactly the kind of turf desired, a result not always to be obtained by sowing the seed.

A lawn of limited extent planted in this way at Washington, D. C., early in September was fairly well covered with grass by December 1st." If the season is a favorable one, this turf will be an even one the second season. The dry midsummer weather will materially check its development. The weeds should be kept down, preferably by mowing them.

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